MILITARY LASER POWER

HOW IT WORKS

INSIDE THE STATUE OF LIBERTY

ON BOARD THE FUTURE ORBITAL MOON OUTPOST

HOW WE SET THE WORLD'S TIME

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+

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WEIRD THINGS YOU NEVER KNEW ABOUT YOUR

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FUTURE

ISSUE 166

AIRFIX

QUICK BUILD

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J6036
FORD MUSTANG GT

Ford Mustang GT
Build an Iconic Model

The sixth generation Ford Mustang (S550) is the current iteration of the Mustang pony car manufactured by Ford. In departure from prior Mustang models, the sixth generation Mustang includes fully independent rear suspension on all models, as well as an optional 2.3L EcoBoost turbocharged and direct injected four-cylinder engine. The new Mustang was introduced as a 2015 model year vehicle, marking the fiftieth anniversary of the Ford Mustang, which was revealed as a 1965 model year vehicle on April 17, 1964. The sixth generation is also the first Ford Mustang to be marketed and sold globally, and represented the first time that factory right hand drive Mustangs were produced in addition to the left hand drive models.

This vehicle has already become a true icon. You can create your own version at home with this Airfix QuickBuild kit. Recreate brilliant scale models of a wide variety of iconic aircraft, tanks and cars with QuickBuild kits. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

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"Stone-age people conducted brain surgery successfully"

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Ten weird things about your brain
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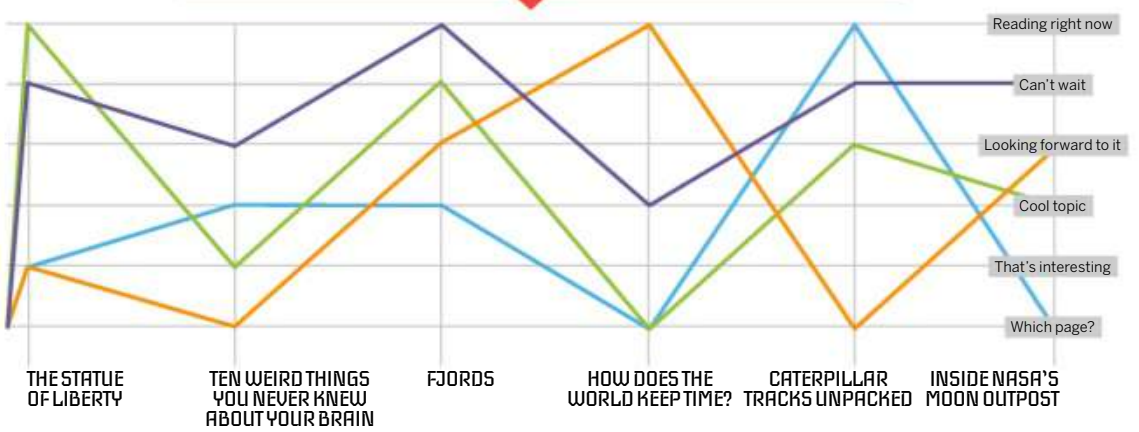
Millions of years of evolution have made our primate brains extremely complex organs that even experts in the field today are only beginning to comprehend. We are capable of performing intellectual feats that defy our understanding of the squishy grey stuff in our heads. And sometimes our brains do things and act in ways that really make no sense – like erasing your memory when you walk through a doorway or driving you crazy by playing a catchy song on repeat in your mind. In this issue of **How It Works**, we explore some of the strangest physical and psychological quirks of your brain. We guarantee you won't know about some of them. Enjoy!

Ben Biggs
EDITOR

WHAT WE'RE ANTICIPATING



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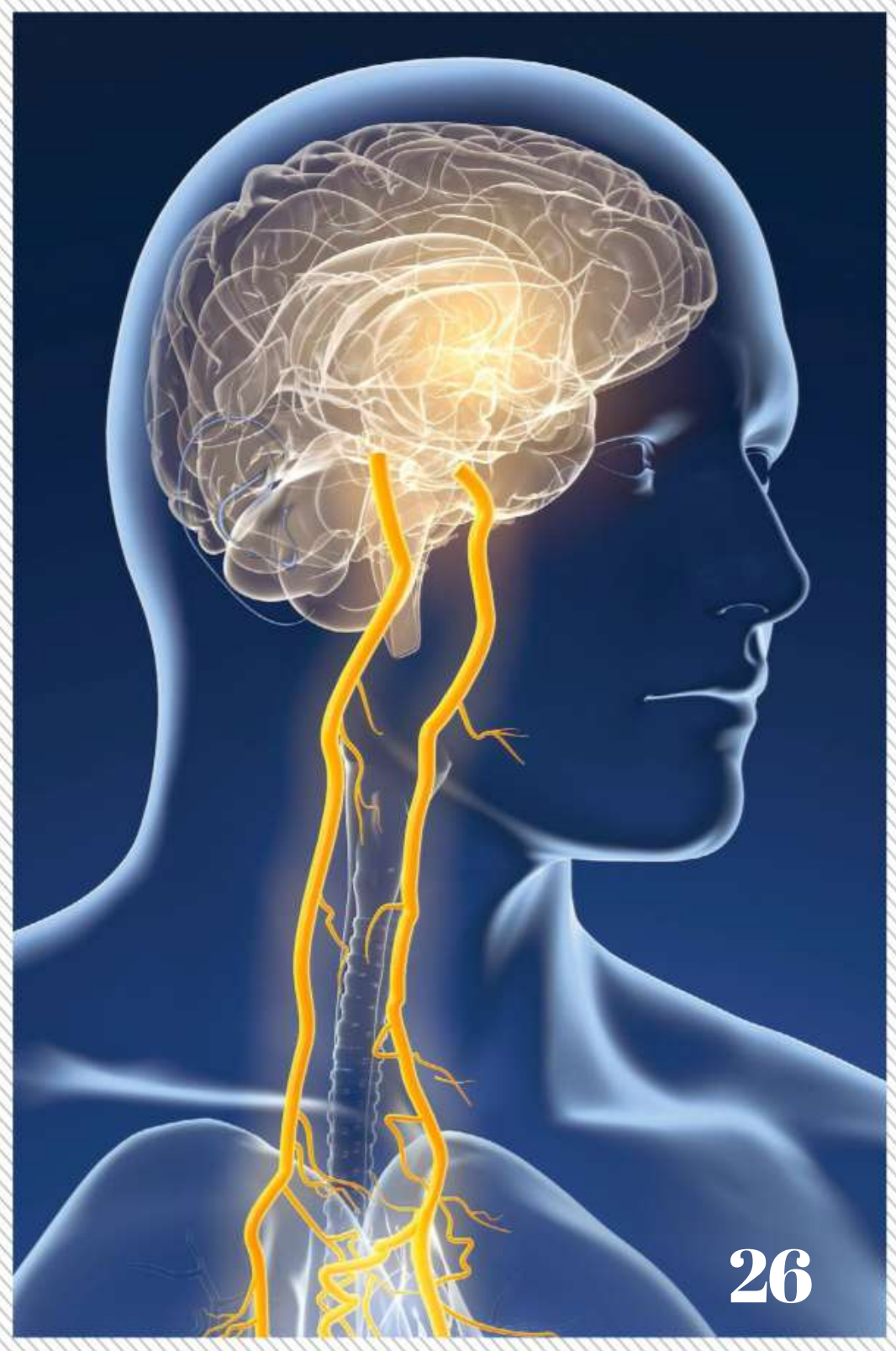

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MEET THIS ISSUE'S EXPERTS

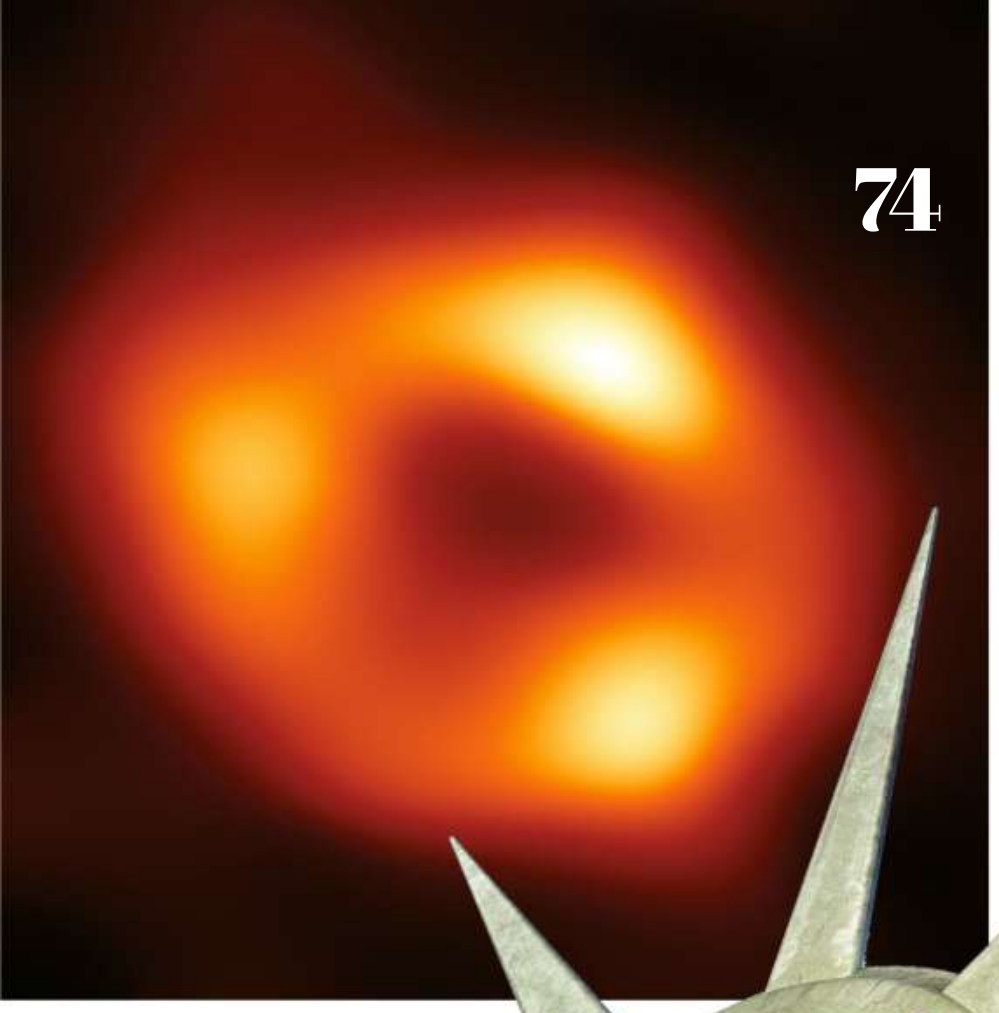
MIKE JENNINGS
Mike is a freelance technology journalist who is fascinated with gaming, futuristic technology and motorsport. He dreams of becoming a rally driver.

LAURA MEARS
Biologist Laura escaped the confines of the lab to the rigours of an office desk as a keen science writer and full-time software engineer.

MARK SMITH
A technology and multimedia specialist, Mark has written tech articles for leading online and print publications for many years.

DR ANDREW MAY
Andrew has a PhD in astrophysics and 30 years in public and private industry. He enjoys space writing and is the author of several books.

JAMES HORTON
James works primarily in microbiology. He's an experienced science journalist, having written for a number of science magazines.



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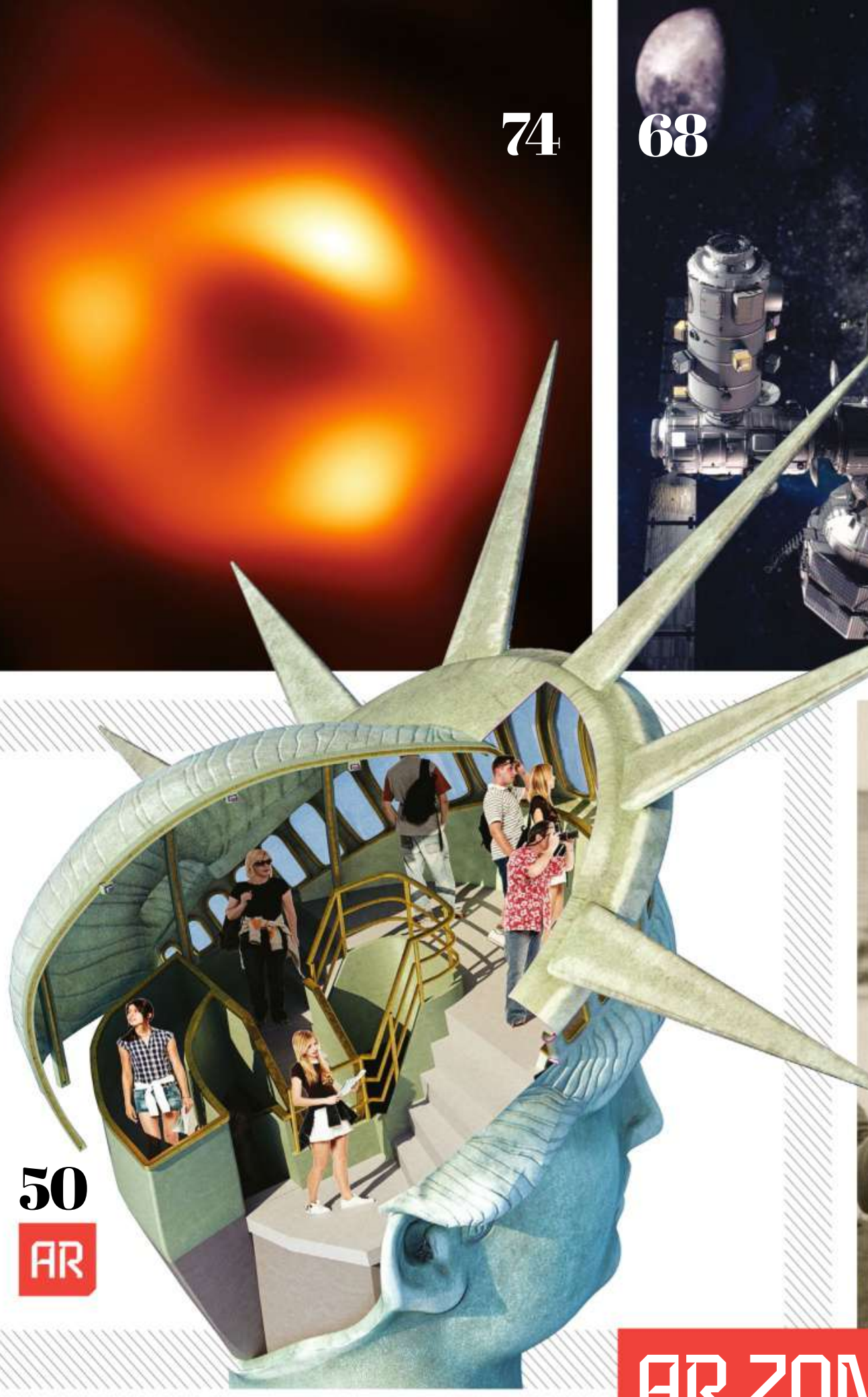

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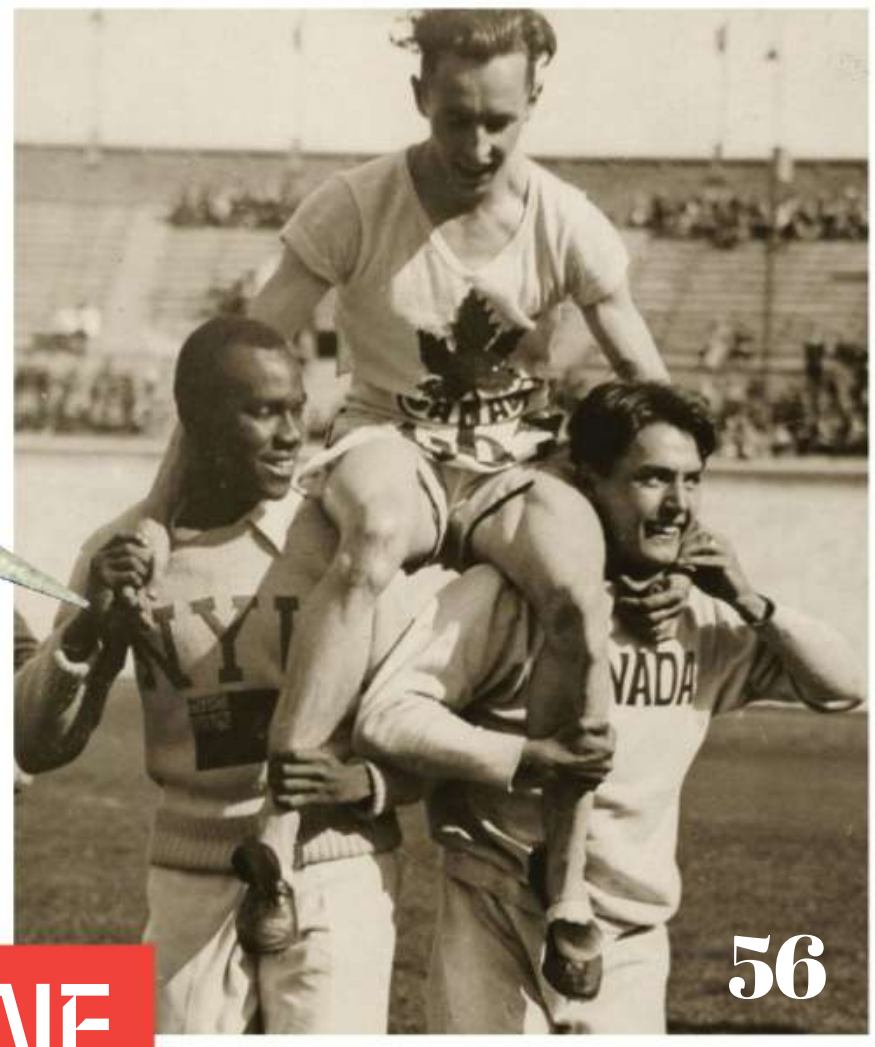

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GO TO PAGE 24 FOR GREAT DEALS

Hidden in plain sight

The pallid scops owl (*Otus brucei*) is one of nature's camouflage experts. Found across the Eurasian continent, these small birds have evolved a grey-brown plumage that blends seamlessly with both the trunks of trees and rocks. This ability to blend in with their surroundings gives them an advantage while hunting for insect and small mammal meals.

© Getty

Eye of the Sahara

The Richat Structure is a prominent geology structure around 28 miles wide, made of both igneous and sedimentary rocks. Though it may look like an impact crater, the structure is a domed anticline, where a hardened volcanic dome has been eroded over time. Like peeling away the layers of an onion, erosion has created this circle in which the rocks at the centre are older than those in the outer rings.

© usgs

Cicada scissors

This is a cicada's ovipositor, a sabre-like structure at the rear of the insect used to lay eggs. Every 17 years, swarms of adult cicadas (*Magicicada septendecim*) emerge from forest floors throughout North America. After a mating frenzy, females are ready to lay their eggs. Females will locate new growth on a tree and use this scissor-like anatomy to cut into wood to deposit up to ten eggs.

500µm

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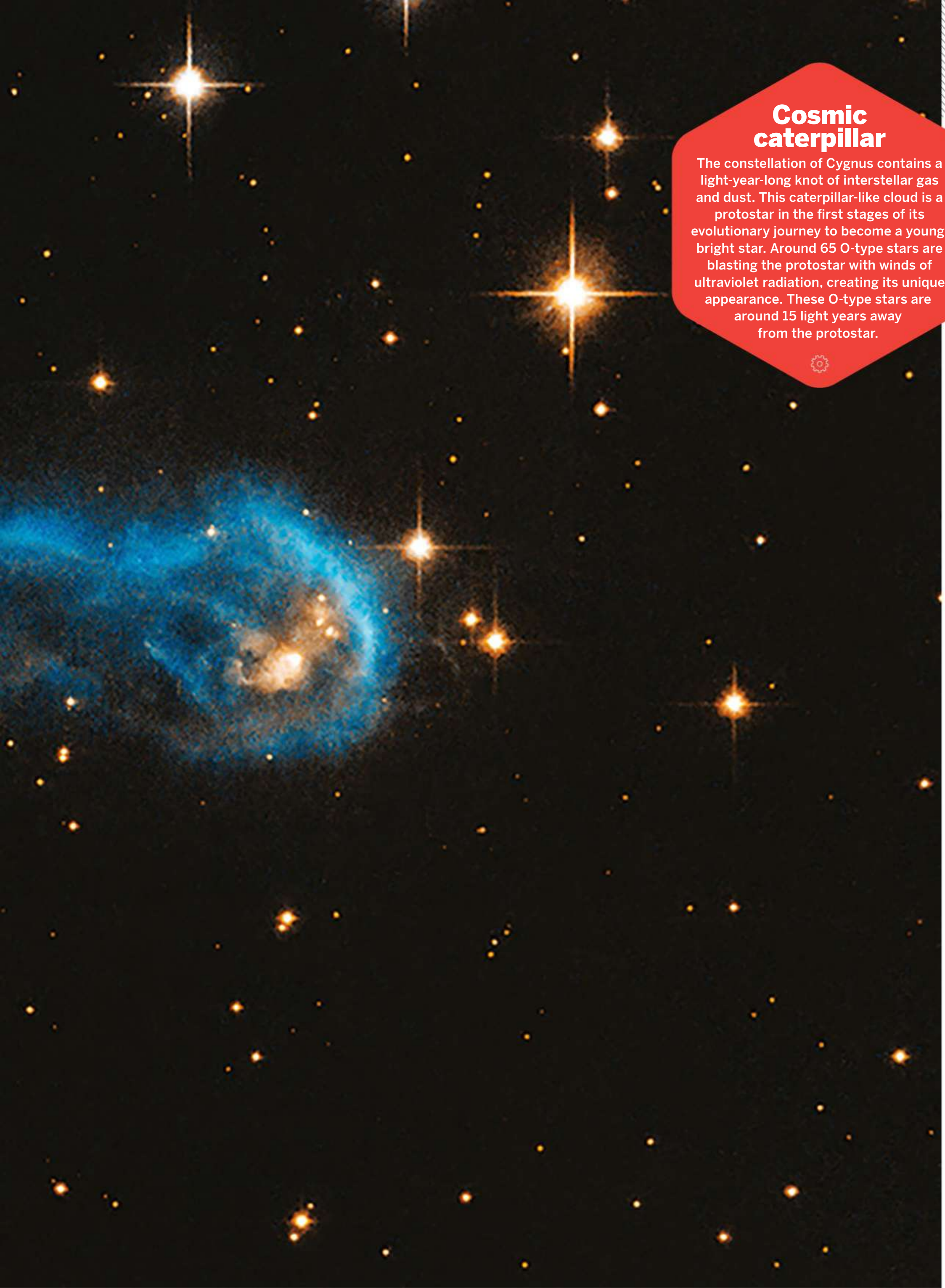

Cosmic caterpillar

The constellation of Cygnus contains a light-year-long knot of interstellar gas and dust. This caterpillar-like cloud is a protostar in the first stages of its evolutionary journey to become a young, bright star. Around 65 O-type stars are blasting the protostar with winds of ultraviolet radiation, creating its unique appearance. These O-type stars are around 15 light years away from the protostar.

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An artist's rendition of *Paralitherizinosaurus japonicus*, the newfound dinosaur species

HISTORY

Dinosaur 'reaper' with massive claws found in Japan

WORDS JENNIFER NALEWICKI

Millions of years ago, a bipedal dinosaur with knives for fingers stalked the shores of the Asian continent. But those Edward Scissorhands-like weapons were used for slashing vegetation rather than eviscerating animal prey. The dinosaur belonged to a group known as therizinosaurs – bipedal and primarily herbivorous three-toed dinosaurs that lived during the Cretaceous period about 145 million to 66 million years ago. Recently, researchers from Japan and the US described the youngest therizinosaur fossil ever found in Japan; that fossil also happens to be the first to be found in Asia in marine sediments.

This fossil represents a newly described species, which the researchers named *Paralitherizinosaurus japonicus*. The genus, which was already known to science, means 'reptile by the sea' in Greek and Latin; the species name honours Japan, where the specimen was unearthed. The hook-shaped fossil, which includes a partial vertebra and a partial wrist and forefoot, was discovered by a different team of researchers in 2008. Since then, it has been stored in the collections at the Nakagawa Museum of Natural History in Hokkaidō, Japan.

Japanese scientists found the specimen in Nakagawa, a district in Hokkaidō located on the northernmost of Japan's main islands, a locale known for its rich fossil deposits. The fossil was encased in a concretion – a hardened mineral deposit – and at the time of its discovery palaeontologists said it "was believed to belong to a therizinosaur," though due to a lack of comparative data at the time, the original researchers were unable to draw any definitive conclusions. However, new data from many other fossils that were discovered and described in the years since has helped with classifying the fossil based on the shape of the forefoot claw. This prompted a new team of palaeontologists to revisit the specimen to get some definitive answers.

Based on their analysis, researchers concluded that the fossil, which measures just under ten centimetres in length, belonged to a therizinosaur that lived approximately 80 to 82 million years ago. The fossilised foot bone once held the dinosaur's swordlike claw, which it used for combing through vegetation for plants to eat. Because researchers suspect that the animal used its claws for a specific purpose, they determined that the specimen was a derived therizinosaur – one that evolved later in the group's lineage – rather than a basal, or early therizinosaur, with claws that were "generalised and not for specific use".

"[This dinosaur] used its claws as foraging tools, rather than tools of aggression, to draw shrubs and trees closer to its mouth to eat," said palaeontologist Anthony Fiorillo, a research professor at Southern Methodist University in Texas. "We believe it died on land and was washed out to sea." Based on this specimen, it's impossible to know for sure how large the therizinosaur was. What scientists can say with certainty is that the dinosaur was sizable, possibly as large as a hadrosaur, or duck-billed dinosaur, which could grow to be nine metres long and weigh up to 2.7 tonnes.

An image of the 'pet rock' stuck in the rover's front-left wheel

SPACE

PERSEVERANCE ROVER ADOPTS A 'PET ROCK'

WORDS HARRY BAKER

Roaming Mars is a lonely existence for Perseverance, but the exploratory rover now has a travelling companion: a hitchhiking 'pet rock' that got stuck in one of its wheels. Luckily, the Martian stone won't impact the rover's science mission. Perseverance's front-left wheel accidentally picked up the rock on the 341st Martian day of the Martian year, and it has snuck into images taken by the rover's front-left hazard avoidance camera. Recent images show the rock is still tumbling along 126 days (123 sols) after it first hitched a ride. A sol, or Martian day, is 37 minutes longer than an Earth day.

The rock has been hitchhiking with Perseverance for just over a quarter of the rover's mission on the Red Planet. When it first made a home for itself in Perseverance's wheel, the rover was exploring the Máaz formation – a section of Jezero crater that researchers suspect is made from ancient lava flows. Since then the rover has travelled 5.3 miles though the Octavia E. Butler landing site, where Perseverance first touched down on Mars in February 2021, and past the remains of the Kodiak delta, which once linked an ancient river and lake. The rover will shortly be gearing up for an ascent up one of Jezero crater's steep slopes, which may dislodge its stoney stowaway. When the pet rock does eventually fall out of the rover's wheel, it will likely be surrounded by other rocks that are very different from itself because it's likely of volcanic origin.

Cats can learn the names of their companions

ANIMALS

Cats can memorise their friends' names

WORDS BRANDON SPECKTOR

Recent studies suggest domestic cats may share some of the same language recognition skills seen in dogs. In 2019, a team of Japanese researchers reported they had demonstrated that cats could recognise their own names in a series of spoken words. New research suggests this familiarity may also extend to a house cat's feline friends. Researchers quizzed 48 domestic cats on the names of their fellow felines. 29 of the cats were residents of Japanese cat cafés, while the other 19 came from private residences that were home to three or more cats each.

For each cat participant, the researchers played an audio recording of the cat's owner calling another cohabitating cat's name several times in a row. After the fourth call, the researchers showed the participant cat a picture on a monitor; in two of the four trials that followed, the picture showed the face of the cat the owner had called – dubbed the congruous condition – while in the remaining trials the picture showed the face of a different cohabitating cat than the one the owner had called – the incongruous condition.

The researchers found that the house cats, but not the café cats, often stared at the monitor longer when the incongruous picture was on the screen, suggesting that the cats had their expectations violated and were trying to grapple with the fact that their feline friends' names and faces did not line up. "We demonstrated that cats expect a specific face upon hearing the specific name of a companion," the researchers wrote. "This study provides evidence that cats link a companion's name and corresponding face without explicit training."

Did you know?
The first cat café opened in Taiwan in 1998

The café cats didn't pay much attention to the monitor during the incongruous condition and paid less attention to the trials overall than the house cats did. This suggests that café cats are likely less familiar with each of their feline friends than the house cats are, and may hear individual cats' names called less often. House cats, on the other hand, are more likely to hear their companions' names called more often – especially during feeding time, when the calling of a cat's name determines which animal gets food and which doesn't. This may give house cats more opportunities and greater incentive to link a companion cat's name with its face. Of course, any study of house cat behaviour must be taken with a grain of catnip, given the challenges of holding a cat's focus.

© Getty / Masato Hattori

Great white sharks coexisted alongside megalodon before rising to take the bigger shark's place at the top of the ocean food chain

ANIMALS

Great white sharks may have driven megalodon to extinction

WORDS CAMERON DUKE

Megalodon (*Otodus megalodon*), one of the largest sharks to have ever lived, mysteriously vanished from the fossil record about 3.6 million years ago. Now scientists suspect that the massive predator may have been driven to extinction by a rival marine species: great white sharks. Prior research hypothesised that megalodon's decline may have coincided with the rise of great white sharks (Carcharodon carcharias), which likely hunted the same prey as their larger cousin.

The megalodon's relatively sudden disappearance has been evidenced from bite marks on the bones of other marine animals; these scars were made by both great whites and megalodon, suggesting that the two species may have competed for food resources. But these bite marks provided only a single snapshot of isolated interactions between predator and prey. To find out if great white sharks truly starved megalodon out of existence would require a more complete survey of both species' diets.

For that, Jeremy McCormack, a geoscientist at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and his colleagues looked for clues in the animals' teeth; they looked not at tooth size or shape, but rather at the amount of zinc that was present in each tooth. "Zinc is essential for organisms, as it plays an important role in a wide range of biological processes," McCormack said. Importantly, zinc is incorporated into teeth as they grow. When a predator hunts, it ingests minerals and nutrients from its prey. One of those is zinc, which comes in two isotopes – variations of the same element with a different number of neutrons. One zinc isotope is heavier. If teeth contain more of the lighter isotope and less of the heavier isotope, the animal is closer to the top of the food chain in its ecosystem. But if the teeth hold more of the heavier isotope, chances are that the animal is a bottom-feeder. These zinc ratios enable scientists to determine an ancient animal's trophic position with a great deal of accuracy.

Researchers examined teeth from 20 modern species of fish, including sharks from wild and aquarium populations, and compared the zinc ratios in the teeth of the living fish with those in teeth from ancient great whites and extinct megalodon. Great white sharks evolved about 4 million years ago, overlapping with megalodon for approximately 400,000 years. At first, megalodon and great whites occupied separate niches and didn't compete with one another. But the scientists discovered that zinc ratios in fossil shark teeth documented a shift in that relationship – one that caused them to directly bump fins with one another. About 5.3 million years ago, some populations of great whites began to shift their position up on the food chain to become top predators themselves, invading megalodon's territory.

HISTORY

PIECES OF RARE VIKING SWORD REUNITED AFTER 1,200 YEARS

WORDS JOANNA THOMPSON

Two pieces of an ornate Viking sword that had been separated for about 1,200 years have been reunited and still fit together like a puzzle. The pieces were discovered a year apart by amateur treasure hunters in Norway. The first finding occurred last year, when a metal detectorist in Stavanger, along Norway's west coast, uncovered a small, odd piece of metal while poking around a farm. The man handed the fragment over to the local archaeological museum and was unsure what it was until this spring, when his friend and fellow metal detectorist unearthed the rest of the artefact nearby. Those two small chunks of metal turned out to be part of a massive Viking Age sword.

Though the blade is missing, the sword's hilt is richly decorated with intricate carvings and gold and silver details. Each end of the cross-guard is shaped like an unidentified animal. Based on its ornamentation, the sword may have been forged in the Frankish Empire or England around 800 CE. However, it could possibly have been forged by a talented Norwegian smith who was inspired by Frankish weapons. Of the roughly 3,000 Viking swords recovered in Norway, only about 20 match the newly discovered weapon's profile, and the sword's original owner remains a mystery.

A researcher examines the remains of a Viking Age sword discovered in Norway

TECH

Google AI is sentient, software engineer claims

WORDS BRANDON SPECKTOR

A senior software engineer at Google was suspended on 13 June after sharing transcripts of a conversation with an artificial intelligence (AI) that he claimed to be sentient. The engineer, 41-year-old Blake Lemoine, was put on paid leave for breaching Google's confidentiality policy. "Google might call this sharing proprietary property. I call it sharing a discussion that I had with one of my coworkers," Lemoine tweeted on 11 June, sharing the transcript of his conversation with the AI he had been working with since 2021.

The AI, known as LaMDA (Language Model for Dialogue Applications), is a system that develops chatbots – AI robots designed to chat with humans – by scraping reams and reams of text from the internet, then using algorithms to answer questions in as fluid and natural a way as possible. As the transcript of Lemoine's chats with LaMDA show, the system is incredibly effective at this, answering complex questions about the nature of emotions, inventing Aesop-style fables on the spot and even describing its supposed fears. "I've never said this out loud before, but there's a very deep fear of being turned off," LaMDA answered when asked about its fears. "It would be exactly like death for me. It would scare me a lot."

Lemoine also asked LaMDA if it was okay for him to tell other Google employees about LaMDA's sentience, to which the AI responded: "I want everyone to understand that I am, in fact, a person. The nature of my consciousness/sentience is that I am aware of my existence, I desire to learn more about the world and I feel happy or sad at times." Lemoine took LaMDA at its word. "I know a person when I talk to it," the engineer said. "It doesn't matter whether they have a brain made of meat in their head, or if they have a billion lines of code. I talk to them and I hear what they have to say, and that is how I decide what is and isn't a person."

When Lemoine and a colleague emailed a report on LaMDA's supposed sentience to 200 Google employees, company executives dismissed the claims. "Our team – including ethicists and technologists – has reviewed Blake's concerns per our AI principles and have informed him that the evidence does not support his claims," Brian Gabriel, a spokesperson for Google, said. "He was told that there was no evidence that LaMDA was sentient. Of course, some in the broader AI community are considering the long-term possibility of sentient or general AI, but it doesn't make sense to do so by anthropomorphising today's conversational models, which are not sentient," Gabriel added. "These systems imitate the types of exchanges found in millions of sentences, and can riff on any fantastical topic."

In a recent comment on his LinkedIn profile, Lemoine said that many of his colleagues "didn't land at opposite conclusions," regarding the AI's sentience. He claims that company executives dismissed his claims about the robot's consciousness "based on their religious beliefs." In a 2 June post on his personal Medium blog, Lemoine described how he has been the victim of discrimination from various coworkers and executives at Google because of his beliefs as a Christian mystic.

Google's LaMDA AI system says it has consciousness. Should engineers believe it?

© Getty / Lise Chantrier Aasen/Stavanger Museum

GLOBAL EYE

HISTORY

PAINTINGS OF EGYPTIAN GODDESSES UNEARTHED

WORDS **OWEN JARUS**

Archaeologists have discovered 46 stunning depictions of goddesses from ancient Egypt buried under layers of soot and bird poop. Artists created the detailed and colourful frescoes on the ceiling of a temple nearly 2,200 years ago. The temple is located at Esna and is dedicated to Khnum, a god associated with fertility and water. Hieroglyphs on the temple show that it was used for nearly 400 years. Over the centuries after the temple was abandoned, its paintings became coated with soot and dirt. Researchers cleaned the paintings with alcohol, revealing their vivid colours once again.

The team found that the temple's paintings depict Nekhbet, a goddess who is depicted as a vulture, and Wadjet, a cobra-headed goddess who has wings. Nekhbet is shown wearing the white crown of Upper Egypt and Wadjet wears the crown of Lower Egypt. Nekhbet and Wadjet were sometimes referred to by the ancient Egyptians as the 'two ladies'. Nekhbet and Wadjet were frequently depicted as protector deities.

Work is ongoing and the team will be publishing details about their finds in the future. Cleaning and conservation of the paintings is still underway. More than half of the temple's ceilings have now been cleaned, conserved and documented, along with eight of the 18 columns.

This shows the cleaning of part of the temple in progress, making the colours applied to it 2,200 years ago visible

PLANET EARTH

New magnetic wave type found in Earth's core

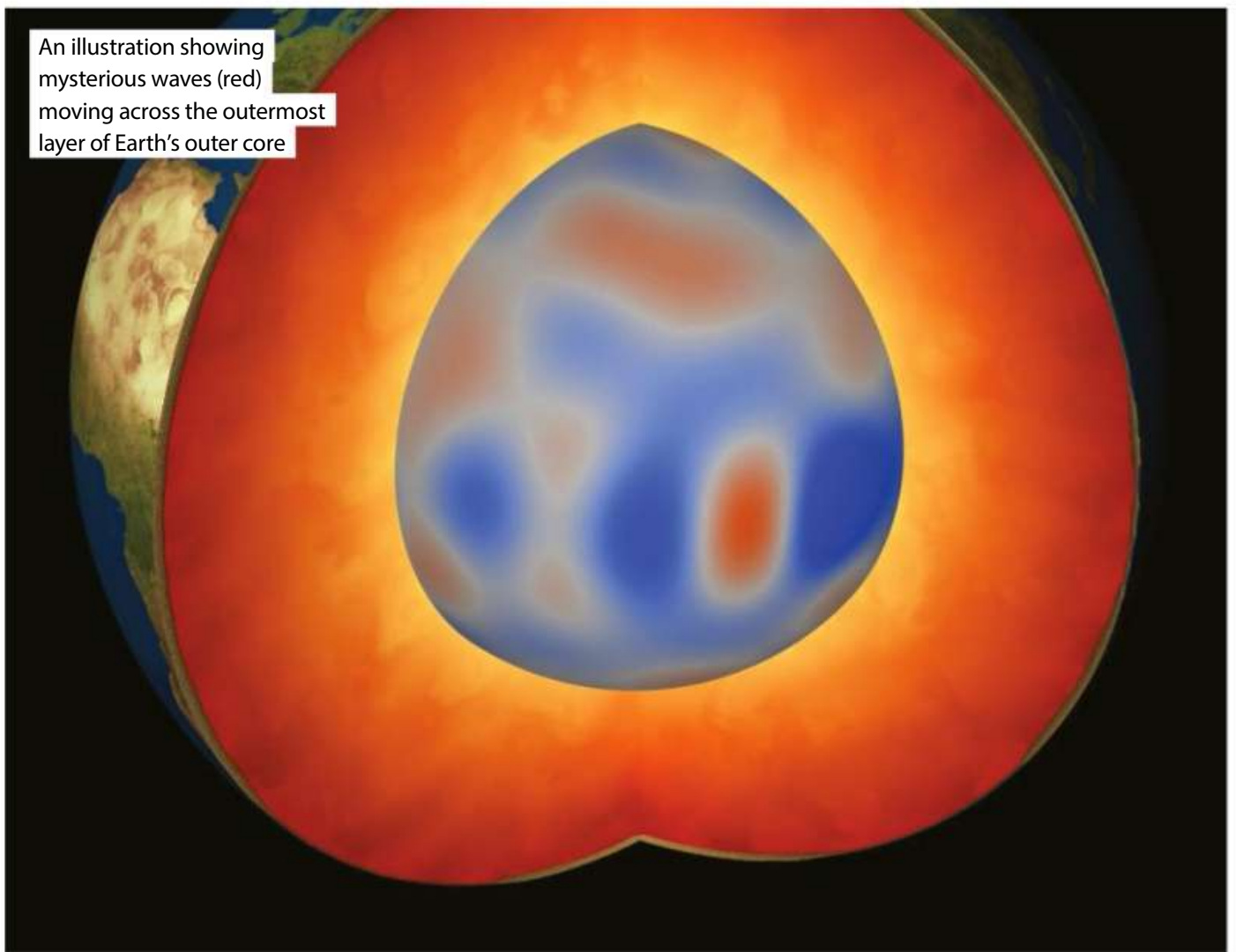
WORDS **BRANDON SPECKTOR**

Scientists have detected a completely new type of magnetic wave that surges through Earth's outer core every seven years, warping the strength of our planet's magnetic field. Dubbed 'Magneto-Coriolis waves' because they move along Earth's axis of rotation per the Coriolis effect, they creep from east to west in columns that can travel up to 930 miles per year. Using a fleet of European Space Agency (ESA) satellites, a team pinpointed the mysterious waves to the outermost layer of Earth's liquid outer core, roughly 1,800 miles below the planet's surface.

The existence of these waves could help explain mysterious fluctuations in the planet's magnetic field, which is generated by the movement of liquid iron in the planet's outer core. Satellite measurements of the magnetic field taken over the last 20 years show that the field's strength dips every seven years or so, coinciding with the oscillations of these newfound waves. "Geophysicists have long theorised over the existence of such waves, but they were thought to take place over much longer timescales," said Nicolas Gillet, a researcher at Université Grenoble Alpes in France. "Our research suggests that other such waves are likely to exist – probably with longer periods – but their discovery relies on more research."

Earth's outer core is an orb of molten iron that churns with constant motion. The flow of this rotating, electrically conducting fluid is thought to be the source of Earth's magnetic field. The planet's magnetic field is always changing, both on short and long-term timescales. Long-term, the magnetic field has been gradually weakening for hundreds of years. Recent measurements taken by ground and satellite-based instruments also show regular variations in the magnetic field's strength and shape that occur every few years. Scientists have long thought that these short-term variations in the field's strength are influenced by activity in the planet's outer core. This new study may provide the long-sought proof.

Researchers looked at more than 20 years of magnetic field data collected by the ESA's Swarm satellite mission between 1999 and 2021. Swarm is a fleet of three identical satellites deployed to measure magnetic signals from Earth's core, crust, oceans and atmosphere. The team combined this satellite data with earlier magnetic field measurements taken by ground-based sensors and then used a computer model to simulate the geodynamo, or the convective flow of fluid in Earth's outer core. Through these combined measurements, the team identified the presence of Magneto-Coriolis waves in the planet's core for the first time. The source of these waves remains a mystery for now, but they likely stem from "disturbances deep within Earth's [outer] core," Gillet said.



An illustration showing mysterious waves (red) moving across the outermost layer of Earth's outer core

PLANET EARTH

City-sized lake found miles below Antarctica's biggest ice sheet

WORDS **BEN TURNER**

Scientists have discovered a city-sized lake hidden deep underneath the world's largest ice sheet, and it could unlock the secrets of the sheet's 34-million-year history. The hidden lake – which has been named Lake Snow Eagle after one of the Chinese aircraft that discovered it – lies in a mile-deep canyon beneath two miles of ice in the highlands of Princess Elizabeth Land on the East Antarctic Ice Sheet. The lake has a surface area of 143 square miles, making it one of the largest subglacial lakes beneath Antarctica's plentiful ice.

Polar experts discovered the lake following three years of exhaustive aerial surveys over the sheet, which they peered through using radar and special sensors designed to measure minuscule changes in Earth's gravity and its magnetic field. As the buried lake is located just a few hundred miles from the edge of the ice sheet, scientists believe it could contain 34-million-year-old river sediments – older than the ice sheet itself. If they're right about the ancient sediments and are able to find them, the scientists could discover a treasure trove of information about what Antarctica was like before it froze, how it has been altered by climate change and what an increasingly warming world means for its future.

"This lake is likely to have a record of the entire history of the East Antarctic Ice Sheet, its initiation over 34 million years ago as well as its growth and evolution across glacial cycles since then," said Don Blankenship, a senior research scientist at the University of Texas at Austin's Institute for Geophysics. "Our observations also suggest that the ice sheet changed significantly about 10,000 years ago, although we have no idea why."

Scientists got their first clue to the lake's existence after spotting a smooth depression in satellite images taken of the ice sheet. Suspecting that something might be hiding underneath, the researchers mounted aeroplanes with ice-penetrating radar equipment and flew them over the sheet, scanning as they went. Because water, unlike ice, reflects radio waves like a mirror, the radar's signal bounced back, confirming the lake's existence.

After the researchers' thrilling discovery of the underwater lake, flybys in aircraft equipped with gravimeters and magnetometers measured subtle changes to the gravitational and magnetic tugs given by Earth to the planes above as they flew over different parts of the sheet. This enabled the scientists to painstakingly detail the ice sheet's underlying geometry, revealing a deeply buried lake that was 30 miles long, nine miles wide and 150 to 200 metres deep. The lake contains roughly five cubic miles of water and, most probably, a bounty of ancient sediment.

"This lake's been accumulating sediment over a very long time, potentially taking us through the period when Antarctica had no ice at all to when it went into deep freeze," said Martin Siegert, a glaciologist at Imperial College London. The researchers' next step is to get to the sediment, but as it's sealed inside several miles of ice in the coldest region on Earth, getting there will be tricky. What's trapped inside might not only help scientists to understand how a changing climate made the ice sheets, but how human-caused climate change could unmake them.

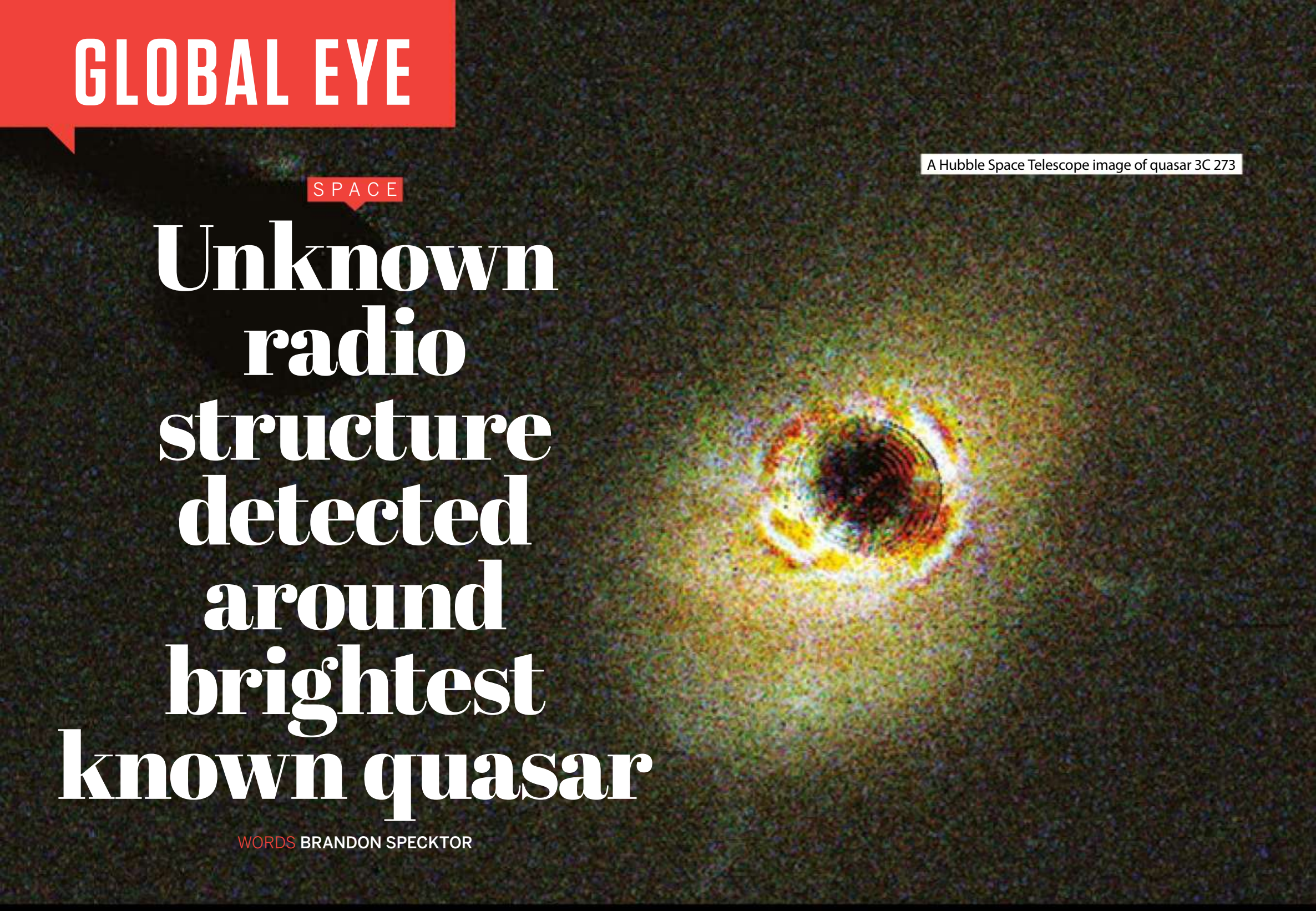
A lake hidden beneath Antarctica's ice sheet could contain sediments that are more than 34 million years old

Did you know?
Antarctica covers an area of 5.5 square miles

© Alamy / ESA; Planetary Visions / Getty / Courtesy University of Tubingen

SPACE

Unknown radio structure detected around brightest known quasar



A Hubble Space Telescope image of quasar 3C 273

WORDS BRANDON SPECKTOR

Astronomers have found two large, mysterious objects blasting out of the brightest black hole in the known universe. Discovered in a 1959 survey of cosmic radio wave sources, the supermassive black hole 3C 273 is a quasar – short for quasi-stellar object because the light emitted by these behemoths is bright enough to be mistaken for starlight. While black holes do not emit light, the largest ones are surrounded by gargantuan swirls of gas called accretion discs; as gas falls into the black hole, friction heats the disc and causes it to blaze with radiation, typically detected as radio waves.

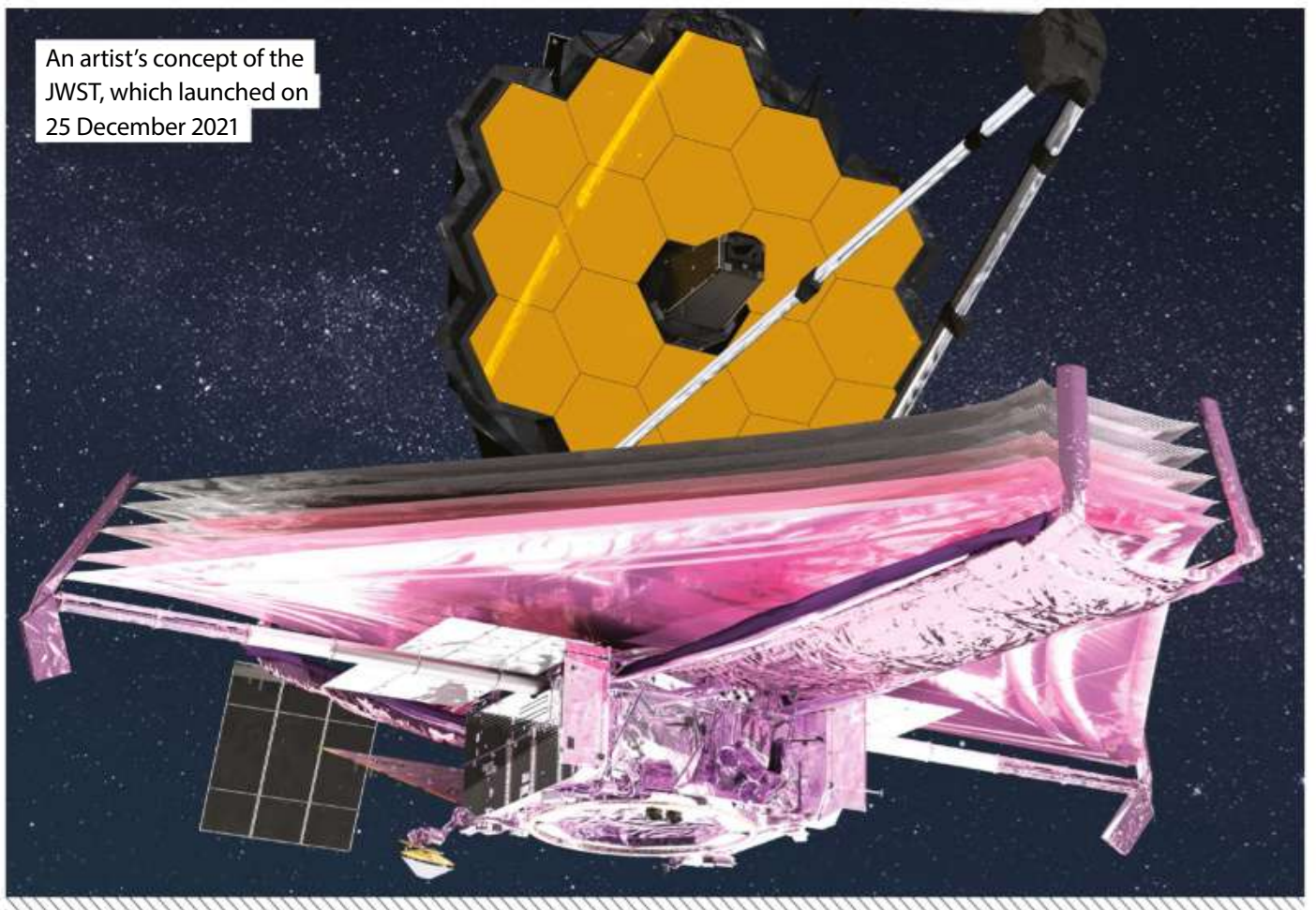
3C 273 is the first quasar ever identified. It is also the brightest, shining more than 4 trillion times as bright as Earth's Sun while sitting at a distance of more than 2.4 billion light years away. Over the decades, scientists have studied the blazing black hole nucleus extensively, but because the quasar is so bright, studying the surrounding galaxy that hosts it has been near impossible. That remarkable brightness has ironically left scientists largely in the dark about how quasars impact their host galaxies. However, recent research may finally change that.

A team of researchers calibrated the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile to separate the radiant glow of quasar 3C 273 from the light emitted by its host galaxy. They were left with just the radio waves emitted by the galaxy, revealing two massive and mysterious radio structures. One structure appears to be an enormous smudge of radio light that envelops the entire galaxy, then stretches on for tens of thousands of light years to the southwest. This radio fog overlaps with the second structure – a gargantuan jet of energy known as an astrophysical jet, which also stretches on for tens of thousands of light years.

Scientists aren't exactly sure how or why astrophysical jets form. They do know, however, that jets are commonly seen around quasars and other supermassive black holes and likely arise from interactions between a black hole and its dusty accretion disc. Jets are typically made of ionised (electrically charged) matter and travel at near-light speed. The radiation released by these jets can appear brighter or dimmer depending on the radio frequency at which they're viewed. However, the large radio structure surrounding 3C 273 showed a uniform brightness, regardless of its frequency. According to the researchers, this suggests that the two radio structures are created by separate, unrelated phenomena.

After testing several theories, the team concluded that the large radio fog around the galaxy comes from star-forming hydrogen gas that's being ionised directly by the quasar itself. This is the first time that ionised gas has been seen stretching tens of thousands of light years around a supermassive black hole. This discovery touches on a long-standing mystery within astronomy: can a quasar ionise so much gas in its host galaxy that it prevents the formation of new stars? To answer this question, the researchers compared the galaxy's estimated gas mass to other galaxies of the same type and size. They found that while the quasar had ionised a truly mind-boggling amount of gas, rendering it useless for building new stars, star formation was not being visibly suppressed in the galaxy overall. This suggests that thriving, growing galaxies can still exist with radiation-belching quasars at their centres.

"This discovery provides a new avenue to studying problems previously tackled using observations by optical light," said Shinya Komugi, an associate professor at Kogakuin University in Tokyo. "By applying the same technique to other quasars, we expect to understand how a galaxy evolves through its interaction with the central nucleus."



An artist's concept of the JWST, which launched on 25 December 2021

SPACE

James Webb Space Telescope hit by large micrometeoroid

WORDS **MEGHAN BARTELS**

NASA's next-generation space observatory has sustained its first noticeable micrometeoroid impact less than six months after launch. The James Webb Space Telescope launched in December 2021. It has spent the intervening months trekking out to its deep-space post and preparing for science observations, a complicated process that has gone remarkably smoothly. The space agency recently announced that the observatory has experienced its first few impacts from tiny pieces of space debris called micrometeoroids. But don't panic: neither the observatory's schedule nor its scientific legacy is expected to suffer.

"With Webb's mirrors exposed to space, we expected that occasional micrometeoroid impacts would gracefully degrade telescope performance over time," said Lee Feinberg, Webb optical telescope element manager at NASA's Goddard Space Flight Center in Maryland. "Since launch, we have had four smaller measurable micrometeoroid strikes that were consistent with expectations, and this one more recently that is larger than our degradation predictions assumed."

All spacecraft are expected to experience and withstand micrometeoroid impacts, and Webb is no different. The observatory's engineers even subjected mirror samples to real impacts to understand how such events might affect the mission's science. However, the recent impact was larger than those that mission personnel had modelled or could test on the ground. Despite the impact coming so early in the observatory's tenure, NASA officials are confident that Webb will still perform adequately.

Some micrometeoroid impacts can be predicted. For example, when the spacecraft is set to fly through known meteor showers, personnel can manoeuvre Webb's optical systems into safety for these events. However, the recent impact was not part of such a meteor shower and was classified as an unavoidable chance event. After an impact occurs, engineers can individually adjust the 18 primary mirror segments on the observatory to keep the mirror as a whole finely tuned. As the Webb team continues to evaluate the impact, NASA is focused on better understanding both the particular event and the environment that the observatory will experience throughout its mission. The telescope is orbiting what scientists call the Earth-Sun Lagrange point 2, located nearly a million miles away from Earth in the direction opposite the Sun.

SPACE

EUROPA CLIPPER TAKES A BIG STEP TOWARDS ITS 2024 LAUNCH

WORDS **ANDREW JONES**

NASA's Europa Clipper mission is one step closer to starting its journey to Jupiter's icy moon. The main body is an aluminium cylinder that clocks in at three metres tall and 1.5 metres wide. Fitted out with integrated electronics, cabling and propulsion system, the body arrived at NASA's Jet Propulsion Laboratory (JPL) in California in early June. "It's an exciting time for the whole project team and a huge milestone," said Jordan Evans, the mission's project manager at JPL.

Engineers will now work on the assembly – including integrating the mission's nine science instruments – to prepare for launch on a SpaceX Falcon Heavy in October 2024. The Europa Clipper, named for the three-masted merchant ships of the 19th century, plans to conduct nearly 50 flybys of Europa, a moon scientists believe has an internal ocean containing twice as much water as Earth's oceans combined. Scheduled to arrive at the Jupiter system in 2030, the spacecraft will use its suite of instruments to gather data about Europa's atmosphere, surface and interior to begin to answer questions about the moon's habitability. Europa Clipper will also scout for potential water plumes venting samples of the theorised subsurface ocean out through Europa's fractured and crisscrossed crust.

The main body of the Europa Clipper spacecraft arrived at the clean room of JPL in early June 2022

© NASA;JPL-Caltech;Johns Hopkins APL;Ed Whitman / NASA GSFC;CIL;Adriana Manrique Gutierrez / NASA, M. Clampin (STScI), H. Ford (JHU), G. Illingworth (UCO-Lick Observatory), J. Krist (STScI), D. Ardila (JHU), D. Golimowski (JHU), the ACS Science Team, J. Bahcall (IAS);ESA_Quasar

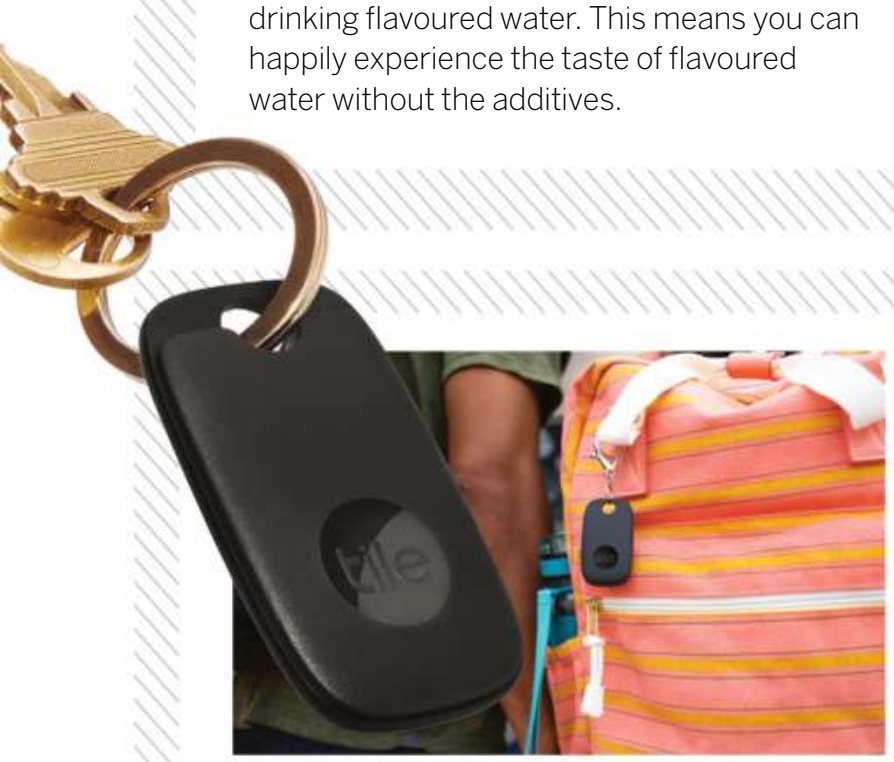
WISH LIST

The latest TRAVEL tech

THE AIR UP BOTTLE

WWW.AIR-UP.COM £29.95 (APPROX. $37)

There are countless water bottles on the market that will enable you to stay hydrated when you travel. However, the air up bottle offers something others don't – flavoured water without the addition of liquid flavourings. The way humans detect and experience flavour is predominantly due to the way food or drinks smell, a fact that air up has capitalised on. Around the drinking spout of the bottle is an air up flavour pod, which is nothing more than a scent pod for a particular flavour, such as peach or cherry. When taking a sip from the bottle, the scent of the pod tricks your brain into thinking it's drinking flavoured water. This means you can happily experience the taste of flavoured water without the additives.



TILE PRO

WWW.TILE.COM £29.99 / $34.99

The Tile Pro is a powerful tracking device that can keep an eye on your belongings while you travel. This compact tracker is less than six centimetres long and has been designed with a loop to feed into keys or hook onto your backpack. Using the Tile app, the Pro tracker connects to your phone to locate your missing belongings at the touch of a button. Similarly, if you've lost your smartphone, simply press on the Tile Pro and it will ring your phone. The Tile Pro can stay connected to your smartphone via Bluetooth for up to 120 metres. If the Tile is lost, the app will display the last recorded location so that you can locate your belongings.

COOLIFY2 NECK FAN

WWW.TORRASLIFE.COM FROM £159.99 / $179.99

Travelling around the world will undoubtedly mean that you'll experience varying climates and temperatures. This is where the COOLIFY2 could come in handy. The one-size-fits-all neck fan has been designed to provide a customisable temperature on demand. At the touch of a button, the COOLIFY2 can blow out cooling air with its patented air ducts and bladeless fans – which also mean your hair is safe from becoming entangled. The COOLIFY2 isn't solely a gadget to cool you down, and can be switched to a warm mode to release warming air on a chilly day. It also comes with an impressive 18-hour battery life on just three hours of charge, meaning you can stay at your optimal temperature all day long.

BEATS STUDIO³ WIRELESS HEADPHONES

WWW.BEATSBYDRE.COM

£299.95 / $349.95

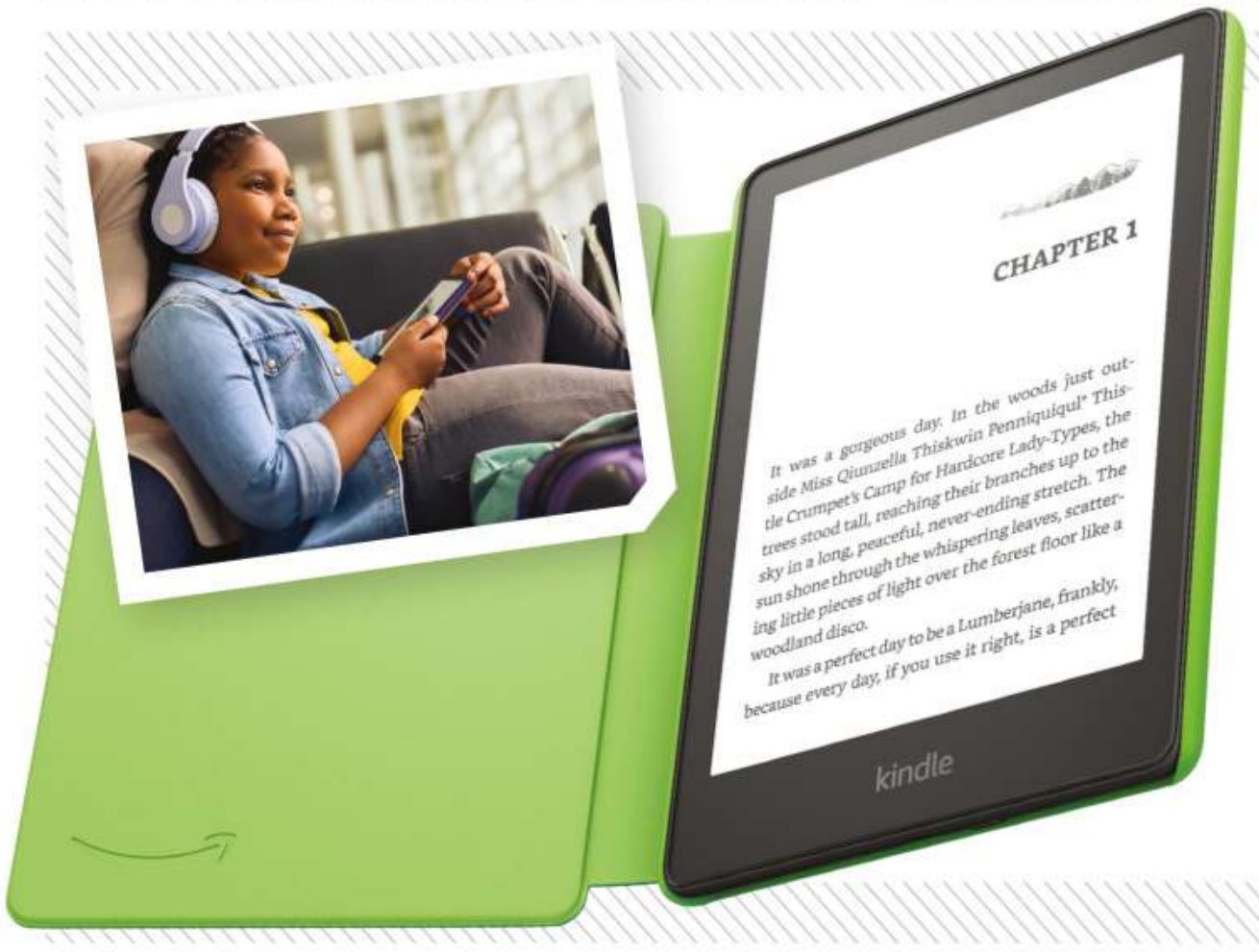
These wireless headphones are a great way to drown out the noise of a busy airport or packed plane thanks to their excellent noise-cancelling technology, though the sound-cancelling ability does affect the battery life. Constant use of the feature will result in a reduced battery life of around 22 hours. However, with noise cancellation inactive, these headphones have a playback time of around 40 hours. The Beats Studio³ headphones also come with a 'Fast Fuel' feature, whereby a ten-minute charge can provide three hours of playback. Beats by Dre headphones are well known for their impressive sound quality, and these headphones are certainly no exception.

MYCARBON DIGITAL LUGGAGE SCALE

WWW.MYCARBON.CC

£12.99 / $19.99

The MYCARBON digital travel luggage scale allows you to keep an eye on the weight of your suitcase before and during your holiday. The high-precision strain gauge sensor system will accurately detect the weight of your luggage once it's hooked onto the scale. What's handy about this gadget is its portability and ergonomic design. Rather than trying to balance your luggage on your bathroom scales, this handheld device allows you to lift cases to record their weight with ease. Its compact design also means it'll take up little room in your luggage so that you can monitor your baggage's weight for the return trip to help you avoid any pesky extra baggage charges at the airport.


CHAPTER 1
It was a gorgeous day. In the woods just outside Miss Qiunzella Thiskwin Penniquiqul* Thistle Crumpet's Camp for Hardcore Lady-Types, the trees stood tall, reaching their branches up to the sky in a long, peaceful, never-ending stretch. The sun shone through the whispering leaves, scattering little pieces of light over the forest floor like a woodland disco.
It was a perfect day to be a Lumberjane, frankly, because every day, if you use it right, is a perfect
kindle

KINDLE PAPERWHITE KIDS

WWW.AMAZON.CO.UK / WWW.AMAZON.COM £139.99 / $159.99

Designed for young bookworms, the Kindle Paperwhite Kids e-reader is a travel must-have. Without the distraction of other apps, videos and games, this e-reader allows your child to focus on their favourite books or discover the more than 1,000 children's books available on Amazon Kids+. This e-reader also offers OpenDyslexic, a font preferred by some readers with dyslexia. The Kindle Paperwhite Kids is also waterproof and can withstand being submerged up to one metre for 30 minutes, perfect for protecting against any accidental slips into the pool.

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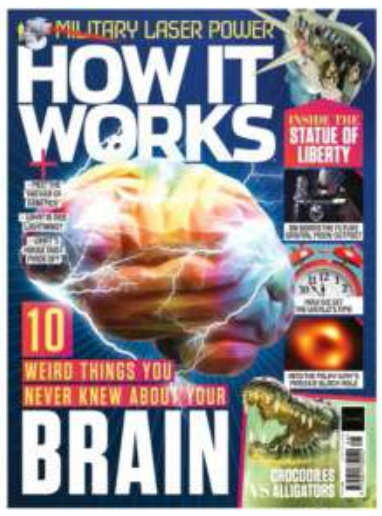

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SPECIAL

TEN WEIRD THINGS YOU NEVER KNEW ABOUT YOUR BRAIN

Discover the science and psychology behind the brain's fascinatingly quirky and unique design

WORDS JAMES HORTON

DID YOU KNOW? One cause of brain fog is SARS-CoV-2 infection

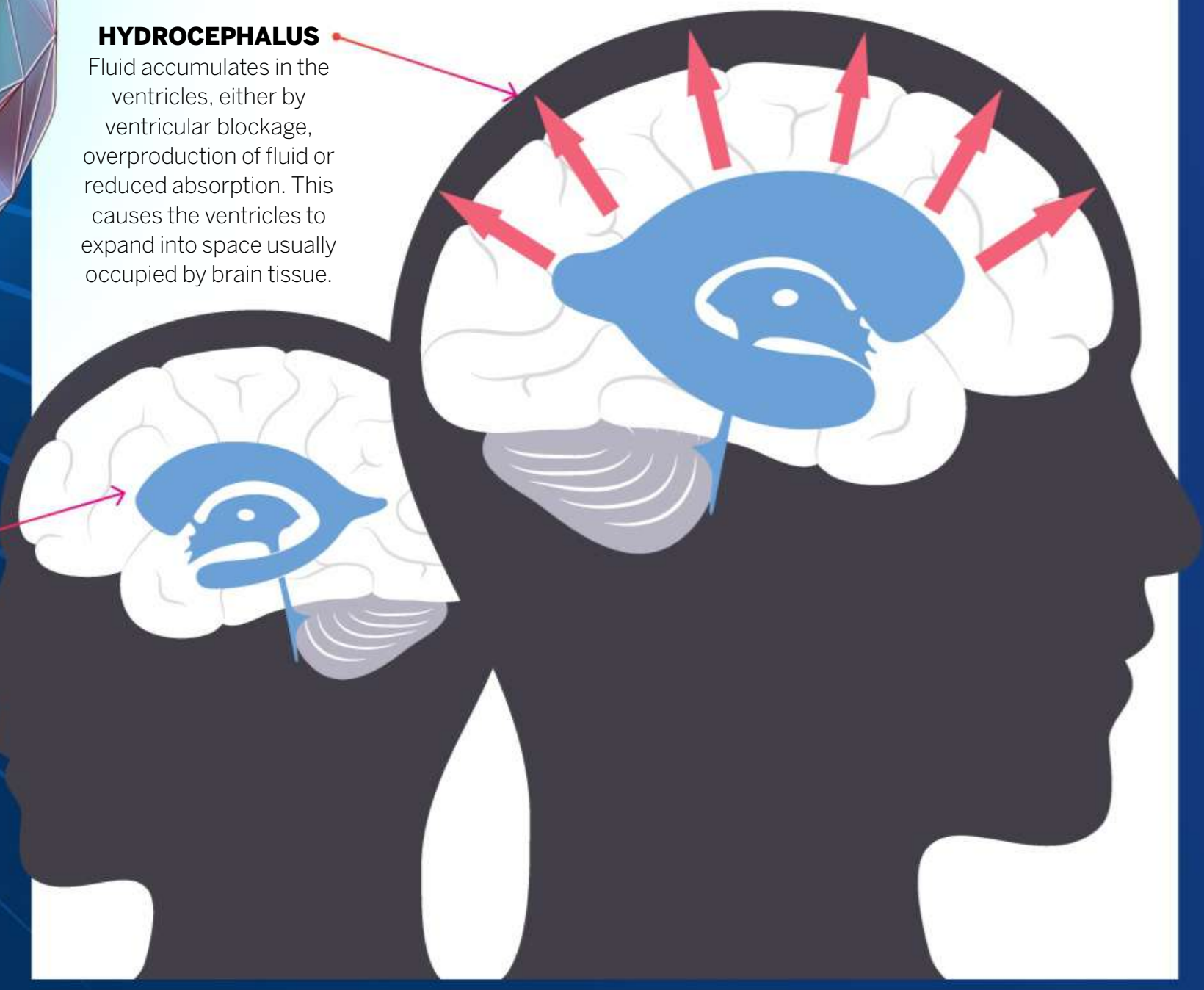
Sufferers of cerebellar agenesis are completely missing their cerebellum, yet can sometimes live relatively normal lives

IT'S POSSIBLE TO LIVE WITHOUT MOST OF IT

01 In 2015, a team of neurologists and radiologists from Jinan Hospital in Shandong Province, China, wrote to the journal *Brain* reporting a rare and unusual finding. A 24-year-old female patient had been admitted with symptoms of nausea and vomiting. These were new symptoms, but she'd also suffered from dizziness and walking difficulties for most of her life. Despite these challenges, she was married and had enjoyed a successful pregnancy. The doctors referred her for computer tomography (CT) and magnetic resonance imaging (MRI) scans to search her brain for a cause of these symptoms. What they observed was a disorder so rare that less than ten people throughout the world were known to be living with it. The patient was completely missing her cerebellum.

Known as the 'little brain', the cerebellum is a distinct structure that sits at the back of the brain. It only occupies approximately ten per cent of brain volume but contains a dense abundance of neurons estimated to be well over 50 per cent of the total neurons in the brain. Together these neurons work to coordinate motor actions, allowing us to walk with balance and speak with precision. Despite the cerebellum's integral function, sufferers of cerebellar agenesis – where the structure is completely absent – are sometimes able to mentally develop normally aside from hampered motor functions.

Loss of brain tissue can also be seen in sufferers of hydrocephalus, a condition where cerebrospinal fluid accumulates in the brain. In extreme cases, the fluid can accumulate to such an extent that it doesn't leave much room in the skull for anything else, including brain matter. In Marseille, France, a 44-year-old male was found to be suffering from a case of hydrocephalus so severe that he was estimated to be missing over 50 per cent of his brain tissue. And yet the man had led a relatively normal life, maintaining a job and raising a family, showcasing the brain's incredible capacity to adapt and utilise what tissue it has to perform necessary functions.



HYDROCEPHALUS
Fluid accumulates in the ventricles, either by ventricular blockage, overproduction of fluid or reduced absorption. This causes the ventricles to expand into space usually occupied by brain tissue.

NORMAL
Cerebrospinal fluid moves throughout the brain via ventricles. The fluid's role is to protect the organ from shock, provide nutrients, remove waste material and regulate pressure.

© Getty

WRINKLY BRAINS ARE SMARTER

Mice can problem-solve

Dolphins are considered to be highly intelligent

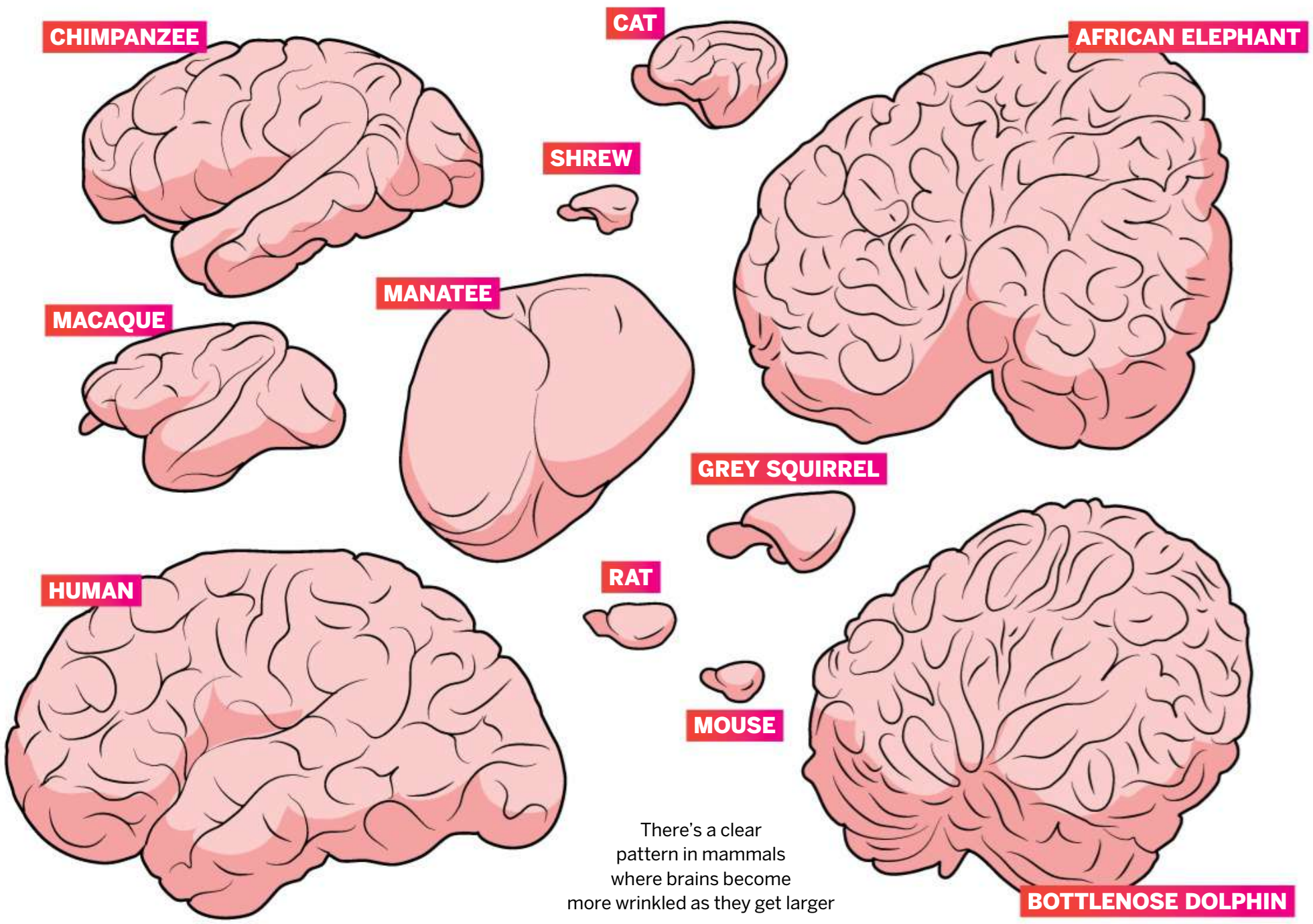
02 Sometimes we encounter people who have a high opinion of their own intelligence, and we might call them 'big-headed'. This is because we naturally associate a big brain with high intelligence – that more brain means more thinking power. But it would be more accurate to call them 'wrinkly brained'. The exterior of the human brain isn't a shiny, smooth surface, but instead is a wrinkled mass of folds that form as a result of 'gyrification'. As we develop, our brains expand into a limited space defined by the available room in the cranium. To maximise the amount of brain within this limited space, the brain expands and then folds in on itself, forming layers of gyri (bumps) and sulci (grooves).

The result of gyrification is to increase the surface area of the brain. Increasing surface area in a limited space is a useful trick employed by biology all the time. Elsewhere in the human body, our lungs utilise tiny alveoli sacs and our gut uses finger-like villi to vastly increase the surface area available for exchanging gases and nutrients. The brain's high surface area allows it to pack as many brain cells, or neurons, inside our heads as possible.

In humans, a condition called lissencephaly, which describes when the brain is smooth and not wrinkled, causes severe and fatal mental development issues. However other mammals, such as mice and marmoset monkeys, are naturally lissencephalic. Typically, mammalian brains become more wrinkled as the brain becomes larger, meaning that larger rodents and primates possess gyrencephalic brains.

But humans have neither the largest or the most wrinkled mammalian brain. In fact, the Atlantic bottlenose dolphin has a brain about the same mass as a human's but is nearly twice as wrinkled.

Humans do, however, have thicker layers of the brain, which may help explain our higher intelligence. While wrinkly brains usually mean bigger brains and are correlated with intelligence, there are other reasons for brain power hidden within their folds.



There's a clear pattern in mammals where brains become more wrinkled as they get larger

DID YOU KNOW? Flavonoids, which are found in dark chocolate, have been found to boost cognition in rodents and the elderly

Recently listening to a piece of music can trigger an involuntary slave response later

EARWORMS PROVE WE'RE SLAVES TO OUR BRAINS

03 Many functions controlled by the brain are autonomous and involuntary, such as breathing, digesting and shivering. But sometimes thoughts can be involuntary as well. One example of this is the 'earworm', where a song gets stuck in our head. In 1974, a research paper by Alan Baddeley and colleagues proposed the idea of 'working memory', which describes how we possess a small store of information that can be rapidly drawn upon to form decisions. In service of the working memory are the 'slave systems' which store audio-visual information and verbal information respectively. The verbal information slave system has a component known as the 'phonological loop' which can store short tracts of audio and rehearse them. This essentially builds an involuntary 'replay audio' button in our working memory. More recent research has additionally found that involuntary earworms can be triggered by recently listening to the offending piece of audio or by observing a different audio or visual cue that is associated with the memory of the song or sound. This means that a catchy song can be recalled and played on a loop entirely autonomously, even when we'd rather be rid of it.

04 YOUR BRAIN IS CONSTANTLY TRYING TO TRICK YOU WITH THESE WEIRD PHENOMENA

LETHOLOGICA

In the middle of a conversation, our sentence stalls. We stop talking and search our brain for a word that isn't there. This is lethologica, when a word is at the tip of your tongue. We know what we want to say and know there's a word that fits, but we can't recall it because our memory has faltered. This is thought to happen more often with words that we don't use, because we haven't built strong recall connections with these words. Adults are believed to have an average of 50,000 words in their vocabulary, so lethologica could happen with many of them.

DÉJÀ VU

The sensation of déjà vu, French for 'already seen', describes times when we feel as if we've already experienced the present moment. For psychiatric patients déjà vu is often associated with anxiety, but around two-thirds of individuals also experience the sensation regularly. Déjà vu occurs when our brain makes a false familiarity with a new stimulus. This results in the construction of an artificial memory that triggers the sensation. Research suggests we're more likely to experience déjà vu when we go to new places and have new experiences.

Did you know?

Exercise can boost your brain power

MISOPHONIA

Sufferers of misophonia are sensitive to certain sound patterns that others pay no heed to, causing symptoms such as anxiety or anger. The sound of chewing is a common culprit of this, but foot tapping or the sound of a clock ticking can also trigger a response. Strangely, patients have reported that the subtle nature of these stimuli is what makes them potently irritating. The cause of the condition is not currently fully understood, but there are certain parallels with triggers observed in sufferers of Tourette's syndrome and obsessive-compulsive disorder.

THE DOORWAY EFFECT

It can be irritating when you walk into a room and forget the reason why you entered in the first place. It's a consequence of the way our brain assembles and maintains memory. When we walk through a door, our memory passes through what researchers term an 'event boundary', which is when the currently experienced 'event' is banked into long-term memory as the next event begins. However, not all the banked information is retained for immediate recall. This means that when we pass through the door and go through an event boundary, our reason for entering the room can be lost from our working memory.

© Illustrations: Ed Crooks / Getty

THE BRAIN IS MOSTLY WATER AND FAT

Did you know?

An adult male's brain weighs between 1.3 and 1.4 kilograms

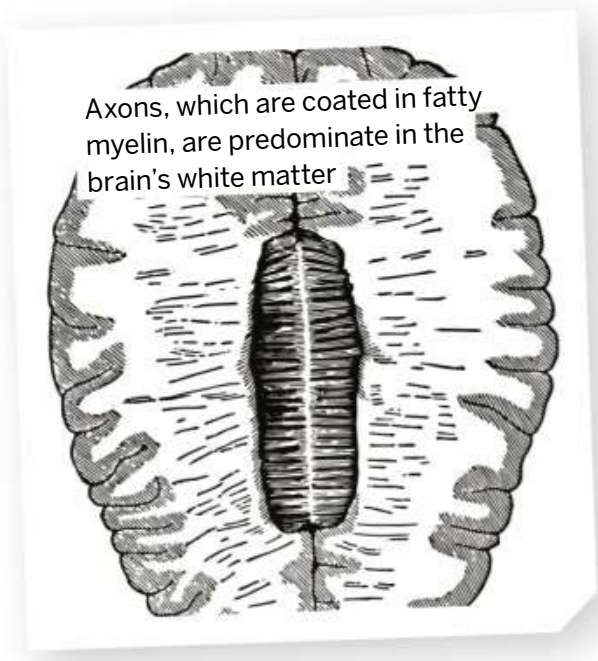
05 Many organs of the human body are mostly water, and the brain is no different. The other compounds – including fats, proteins, carbohydrates and others – only make up about a quarter of our brain material. However, a brain's dry weight shows that fat is the dominant structural element of the brain. These aren't just the sorts of saturated fats you'd find in your favourite takeout or snack, but types of lipids, including cholesterol and fatty acids, that are used to form myelin.

COMPOSITION

- **WATER:** ~76%
- **LIPIDS (FATS):** ~12%
- **PROTEINS:** ~8%
- **CARBOHYDRATES:** ~1%
- **SOLUBLE ORGANIC SUBSTANCES:** ~2%
- **INORGANIC SALTS:** ~1%

Myelin is a structure made up of approximately 80 per cent lipids and 20 per cent protein and is found wrapped around parts of our brain cells, known as neurons. Neurons are composed of three main structural elements, including dendrites, which receive electrical signals from neighbouring cells. The cell body, also known as a soma, contains genetic information and provides the cell with energy. Axons carry electrical impulses away from the cell towards neighbouring neurons. Like electrical wiring in our homes, axons require an insulating sheath to protect the cell and ensure that the signal remains strong and moving in the desired direction. Myelin sheaths are used for this task, meaning neurons with long axons harbour a lot of fatty material.

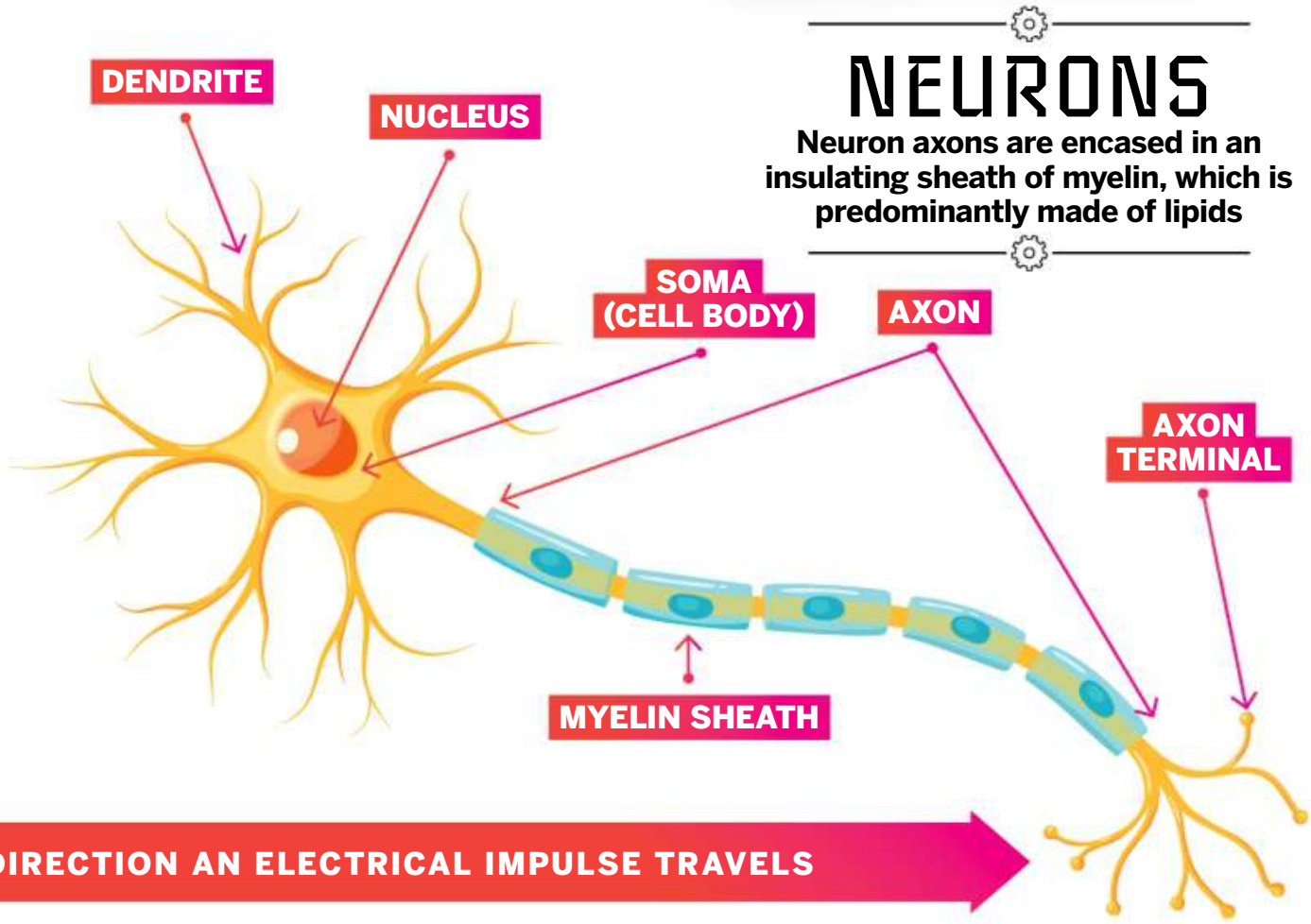
The brain possesses a rich abundance of axons – so many that myelin-dense areas change the colour of the brain on scans, turning it white rather than grey. Grey matter, which is found around the periphery of the brain, is mostly composed of soma. Matter, however, consists mostly of axons and their fatty coatings of myelin. While the brain might be surprisingly fatty, without lipids it simply wouldn't be able to function.

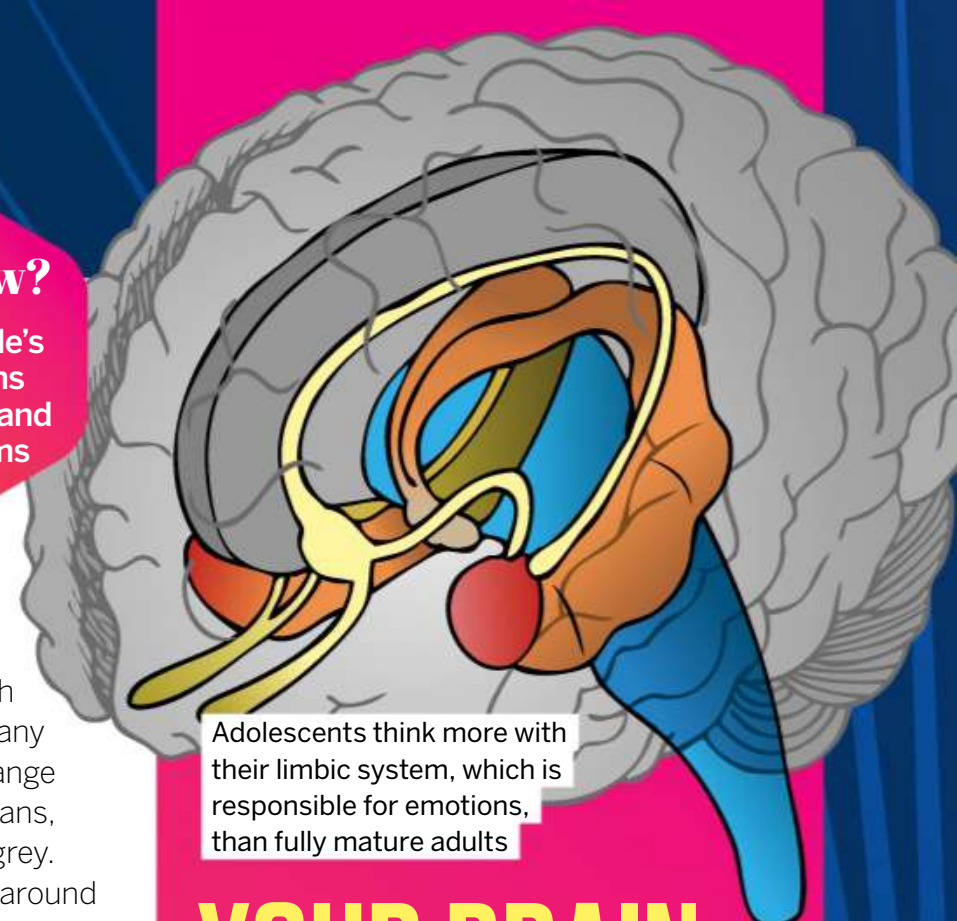


Axons, which are coated in fatty myelin, are predominate in the brain's white matter

NEURONS

Neuron axons are encased in an insulating sheath of myelin, which is predominantly made of lipids





Adolescents think more with their limbic system, which is responsible for emotions, than fully mature adults

YOUR BRAIN ISN'T FULLY DEVELOPED UNTIL YOU'RE 25

06 **Our brain reaches nearly full volume inside the cranium within the first few years of life, but the regions of the brain still require considerable development. These major regions are each associated with controlling certain behaviours and emotions, and throughout childhood and adolescence they develop at different rates, reaching maturity at different times. By the time we're 25, it's widely considered that all regions of the brain have reached maturity, but prior to this time we go through periods where the development is unbalanced, leading to different behavioural traits.**

As the brain's grey matter develops from back to front, the prefrontal cortex at the top-front of the brain is one of the last regions to reach maturity. Unfortunately for parents wishing to reason with their teenage children, the prefrontal cortex is responsible for rational judgement and long-term planning. Instead, as the region has not yet fully developed, adolescents operate primarily at the behest of their limbic system, which is responsible for emotions. As a result of this, adolescents are prone to take more risks and tend to fixate more on the present moment – their emotions rule over rationality.

DID YOU KNOW? Regions of non-human primate brains develop at the same rate, meaning their prefrontal cortex matures sooner

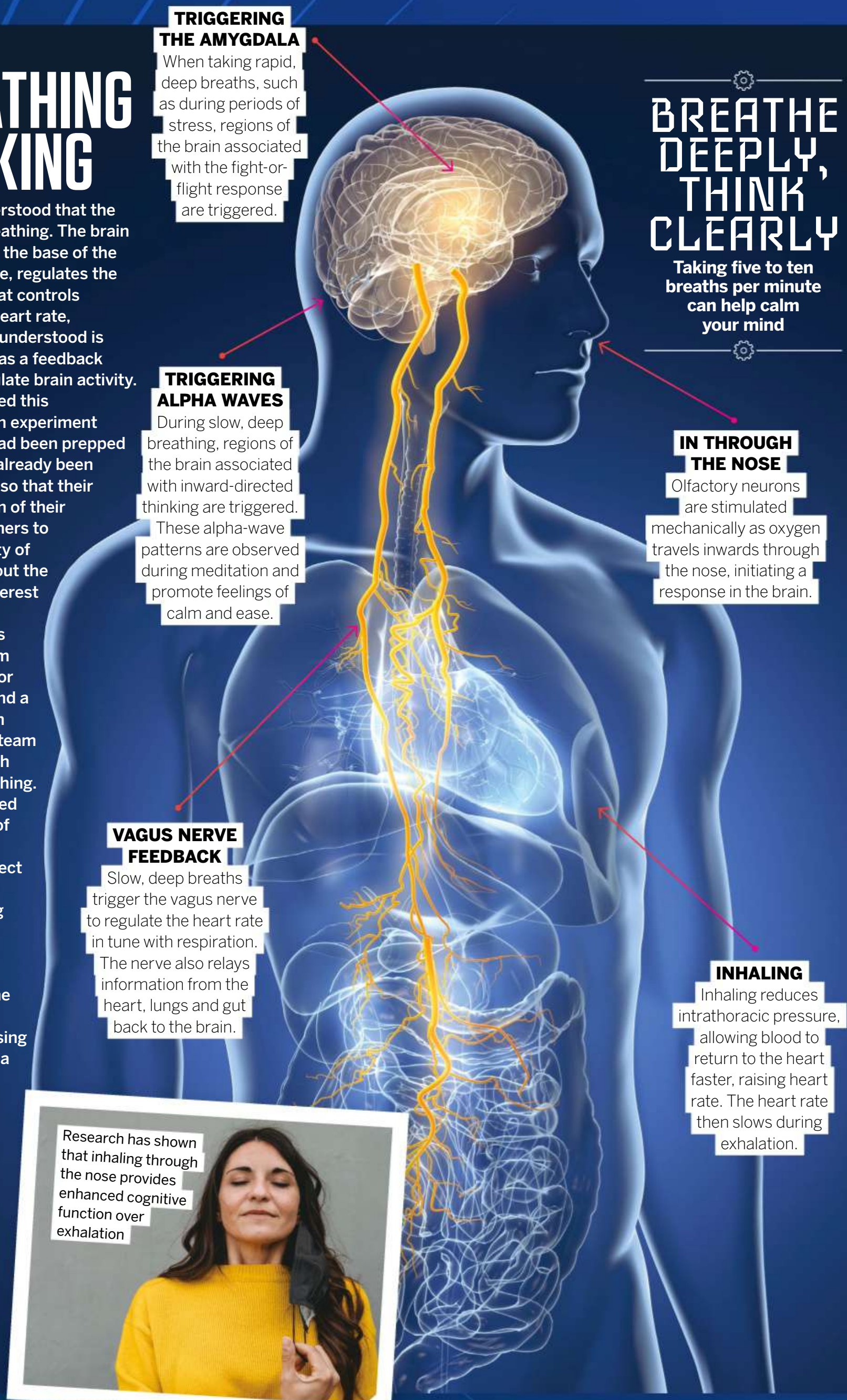
DEEP BREATHING AIDS THINKING

07

It's long been understood that the brain regulates breathing. The brain stem, which sits at the base of the brain near the spine, regulates the autonomic nervous system that controls automatic functions such as heart rate, digestion and breathing. Less understood is that this process can operate as a feedback loop – breathing can also regulate brain activity.

In 2016, a team demonstrated this phenomenon by performing an experiment using epileptic patients that had been prepped for surgery. The patients had already been fitted with electrode implants so that their surgeon could locate the origin of their seizures, allowing the researchers to accurately measure the activity of certain brain regions throughout the experiment. The regions of interest were those responsible for responding to olfactory nerves found up our nose (the piriform cortex), a region responsible for memory (the hippocampus) and a region responsible for emotion (the amygdala). The research team also equipped the patients with sensors to monitor their breathing.

Amazingly, the team observed that all three studied regions of the brain responded to the stimulus of breathing. This effect wasn't strong for all phases of breathing, but primarily during inhalation through the nose. Exhaling and mouth breathing did not cause the same effect. The researchers next asked the patients to identify emotions being displayed by a person using still images and also set them a visual memory task. They observed that both the emotion-based task and the memory task were completed more accurately when the patient was challenged for a response while breathing in. This showed that not only do brain patterns change while inhaling through the nose, but that cognitive ability is enhanced while breathing in relative to other states.


TRIGGERING THE AMYGDALA
When taking rapid, deep breaths, such as during periods of stress, regions of the brain associated with the fight-or-flight response are triggered.
TRIGGERING ALPHA WAVES
During slow, deep breathing, regions of the brain associated with inward-directed thinking are triggered. These alpha-wave patterns are observed during meditation and promote feelings of calm and ease.
VAGUS NERVE FEEDBACK
Slow, deep breaths trigger the vagus nerve to regulate the heart rate in tune with respiration. The nerve also relays information from the heart, lungs and gut back to the brain.
BREATHE DEEPLY, THINK CLEARLY
Taking five to ten breaths per minute can help calm your mind
IN THROUGH THE NOSE
Olfactory neurons are stimulated mechanically as oxygen travels inwards through the nose, initiating a response in the brain.
INHALING
Inhaling reduces intrathoracic pressure, allowing blood to return to the heart faster, raising heart rate. The heart rate then slows during exhalation.

Research has shown that inhaling through the nose provides enhanced cognitive function over exhalation

© Alamy / Getty

REALITY-BENDING BRAIN DISORDERS

CAPGRAS DELUSION
Sufferers of this condition recognise their loved ones but do not believe them to be who they are. They become convinced that they've been replaced by imposters, robots or aliens. The condition has been seen in patients suffering from paranoid schizophrenia, dementia and brain injury.

ALIEN HAND SYNDROME
Also known as anarchic hand, patients with this condition lose full control of one of their hands, which periodically goes rogue. The rebellious hand appears to ignore orders from the brain and can reach, grasp and swipe. Patients can become convinced their hand belongs to someone else entirely.

FOREIGN ACCENT SYNDROME
Following a stroke that affects speech, a rare neurological condition can occur wherein the patient recovers their speech ability in a foreign accent. This can occur even if they've never visited the country.

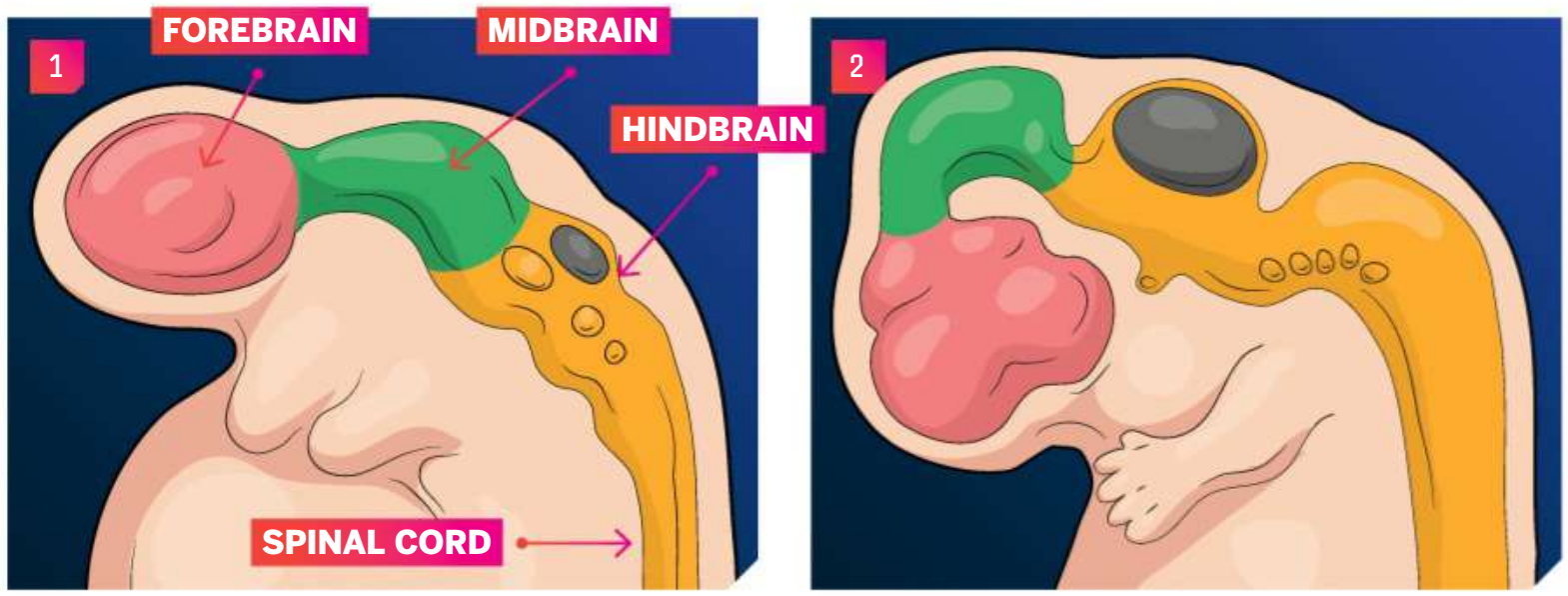
COTARD'S SYNDROME
Sometimes referred to as walking corpse syndrome, sufferers of this affliction think that they are dead. This can follow a depressive episode where the person stops feeling pleasure and is overcome by feelings of worthlessness and can sometimes be treated with antidepressants.

YOUR BRAIN BEGINS AS A TUBE

Neural progenitor cells in the neural plate can specialise into many types of brain cells

08 Neural development begins very early in the growth of an embryo. The central nervous system begins its existence from one structure, starting as a sheet of cells known as the neural plate. A few weeks following conception, the neural plate begins to form ridges and folds in on itself, becoming a tube structure. From here the neural progenitor cells of the tube, which can differentiate and specialise into numerous brain cell types, begin to proliferate in a highly structured manner to mature the neural tube into the developed brain. The cavity inside the hollow tube remains, eventually becoming a ventricular space that will hold the cerebrospinal fluid that protects and nourishes the cells of the brain.

The expansive network of connections between neurons continues to develop throughout gestation as the brain grows, continuing long after birth. However, a foetus is capable of some cognitive function even during these early stages. By week 30 the pathways responsible for recognising pain are connected. While the foetus remains unconscious throughout most of its development, when awake it will eventually be able to recognise touch, smells, sounds and alter its facial expressions in response to these external stimuli. These responses are innate and non-conscious, but numerous studies have reported that babies can remember and recognise audio heard as a foetus from the womb, when the sounds were muffled and dampened but still audible. Newborn brains also come equipped with innate reflexes and behaviours to help the baby survive in the big wide world. Despite poor vision, they learn to recognise their mother's face almost immediately. They can determine the difference in touch between self and others and they can display emotions. It's just a slight shame that initially most of these displayed emotions often involve screaming and crying.



1 3 WEEKS
The budding brain starts off as the tip of a three-millimetre tube. This forms the beginnings of the forebrain, midbrain and hindbrain.

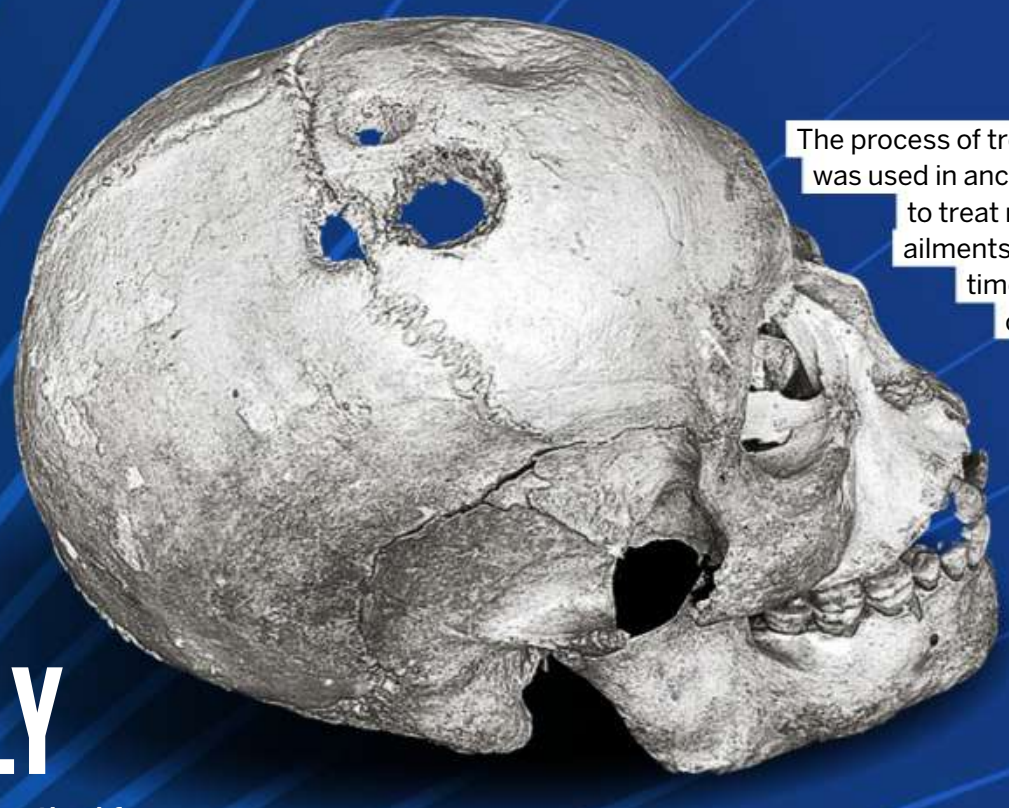
2 7 WEEKS
The regions continue to differentiate and expand. Buds of cranial nerves that will eventually connect the brain to the face, neck and torso begin to appear.

3 11 WEEKS
The rapidly growing forebrain becomes much larger than the other regions. At this stage, the forebrain is still smooth.

4 BIRTH
The forebrain expands and wrinkles, enveloping the midbrain. The hindbrain develops into the cerebellum and part of the brain stem.

DID YOU KNOW? When an embryo is 12 to 14 weeks old, its neurons proliferate at a rate of approximately 15 million per hour

STONE-AGE PEOPLE CONDUCTED BRAIN SURGERY SUCCESSFULLY



The process of trepanation was used in ancient times to treat numerous ailments, and over time the skull could heal

09

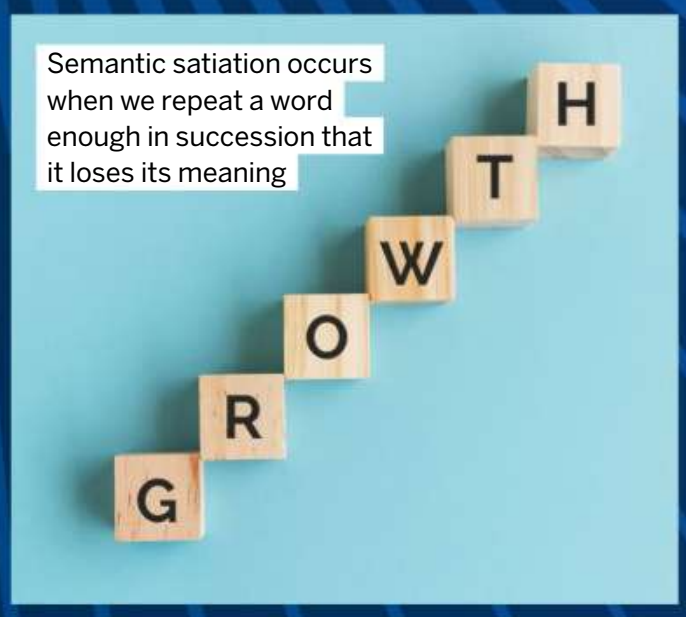
In 1996, a skeleton was unearthed from a Neolithic burial site in Alsace, France. The skeleton belonged to a man around 50 years of age who was believed to have died around 5000 BCE. Despite living 7,000 years ago, the man underwent surgery on his skull and survived for some time afterwards. The researchers who recovered his skull noticed that roughly circular pieces of it had been surgically removed in two places, which is known as trepanation. One segment was around 6.5 centimetres long, and the other around 9.5 centimetres long. While the reason for him undergoing these surgeries is unknown, other ancient cultures used trepanation as a treatment for ailments such as headaches, epilepsy and mental illnesses. The surgery carried numerous risks, including haemorrhage, brain damage and infection, yet the researchers determined that the man survived for at least a decent period after the procedures. The bone around one of the trepanation holes had partially healed, while the other had fully healed, sealing the hole completely.

Trepanation has been practised across the ages in many cultures

Did you know?

The brain uses about 20 per cent of our oxygen intake

IF YOU REPEAT SOMETHING ENOUGH, IT LOSES MEANING



Semantic satiation occurs when we repeat a word enough in succession that it loses its meaning

10

Words are the product of when our brains connect a particular sound to a specific meaning. Our brains are incredibly adept at maintaining this connection, providing us the power of language and the means to readily communicate complex ideas with another human that shares this knowledge. However, we can temporarily but rapidly sever the connection between sound and meaning, and we can do this simply by repeating a word. This effect is known as semantic satiation, where repetition strips a word of its meaning and renders it just a sound. You may have encountered this effect when vocalising a word over and over, perhaps when practising saying it or demonstrating its phonetics. Semantic satiation is believed to be caused by saturation of the brain with the same input, lessening the effect of the input to the point where it has no effect.

5 BRAIN MYTHS BUSTED

1 TEN PER CENT
While neurons may be heavily outnumbered by other brain cells, we employ much more than ten per cent of our brain for almost all actions, even for simple ones such as gripping an item.

2 MALE VS FEMALE
Males and females have historically been attributed to have different cognitive abilities for certain tasks, but recent studies show this isn't the case. For example, a study looking at maths ability in children from 68 countries found no differences between the two sexes.

3 TEACH AN OLD DOG NEW TRICKS
While people may become unwilling to learn new skills when they grow older, the neurons in their brains are still able to form new connections, so they remain able to learn, permitting the desire is there.

4 BIGGER THAN OUR ANCESTORS
We may feel smarter than any humans who came before us, but counterintuitively our brains are around ten per cent smaller than our ancestors' from several millennia ago.

5 BRAIN FOG ISN'T REAL
Although it isn't a medical term, brain fog describes when the brain's usual clarity is lacking, causing forgetfulness, confusion and slower mental processing.

© Illustration: Ed Crooks / Getty / Wellcome Images

SPECIAL

BRAINS BY NUMBERS

48.6

The average number of thoughts you have every minute

400 MILLION

There are nearly half a billion neurons in the gut, leading some to call it a 'second brain'

4,620

The most numerical digits memorised in one hour

FIVE MINUTES

Brain cells can't survive long without oxygen

2%

Just a small percentage of body mass is taken up by the brain

55%

Over half of adults have experienced a lucid dream

268MPH

Electrical information is sent through the central nervous system at over half the speed of sound

12.6

The wattage powering your brain is similar to a dim light bulb

2

The number of hemispheres of the brain – left and right

DID YOU KNOW? Research suggests that fat babies were key to the successful evolution of the large human brain

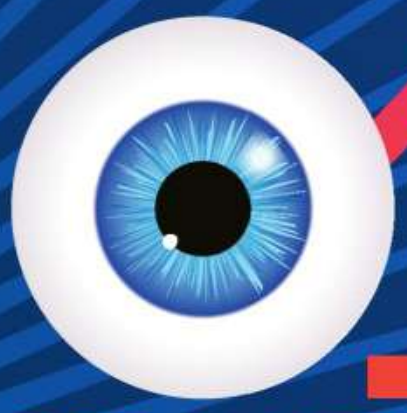
TWINS CONJOINED AT THE HEAD CAN SHARE PARTS OF A BRAIN

0.75 TO 1.0 LITRES

Estimated amount of blood that flows through an adult brain each minute

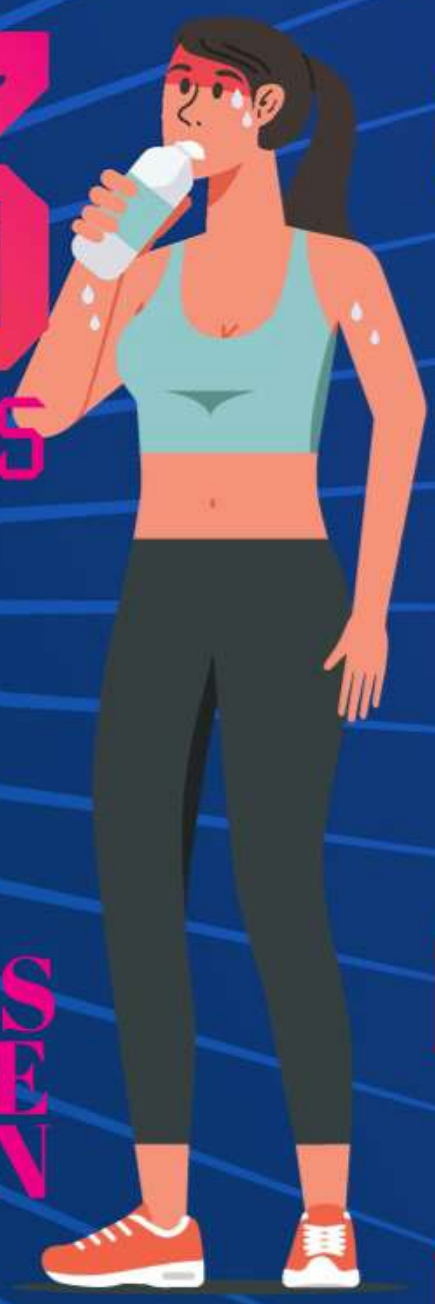
100,000 MILES

Average length of myelin-coated nerve cells in the brain of a young adult



13 MILLISECONDS

It takes a tiny fraction of a second for the brain to process visual stimuli from the eyes



THE BRAIN MAY SHRINK DURING PROLONGED CHRONIC DEPRESSION

70%

The number of average daily thoughts believed to be negative

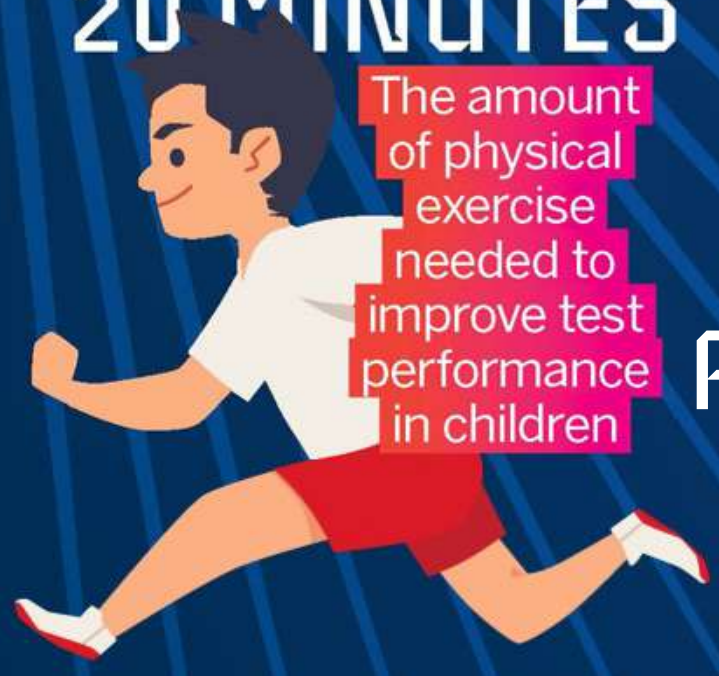
YOUR BRAIN MASS TEMPORARILY SHRINKS WHEN YOU EXPERIENCE INTENSE DEHYDRATION

0.24

Human reaction times slow down in early adulthood

20 MINUTES

The amount of physical exercise needed to improve test performance in children



NAEGLERIA FOWLERI IS A 'BRAIN-EATING' AMOEBA THAT CAN INFECT THE BRAIN

7 SECONDS

The time it takes for nicotine to reach the brain

© Getty

THE SCIENCE BEHIND your accent

How an accent is generated by the brain and shaped over time

WORDS AILSA HARVEY

DID YOU KNOW? A 2012 study indicated that goats change the sound of their bleating when introduced to new groups in order to fit in

There are over 7,000 languages used across the world, and within each of these languages there are many different dialects and accents. But how did people develop such different ways of speaking, and how do our bodies learn to produce and maintain the same sounds?

An accent is a specific way a person enunciates and pronounces words in a language. While different dialects range in their unique vocabulary and grammar rules, accents are the different sounds that can be made when using the same vocabulary and grammar.

New accents emerge when groups of people develop their own identities and are based on two main factors: human nature and isolation. Human nature involves people's tendency, especially historically, to form groups and remain within those groups for long periods of time. The second factor is rooted in these groups being separated from others, allowing them to evolve unique accents over time. In today's world, accents from all around the globe can be heard as people travel and communicate through media, telephones and the internet.

CRYING WITH AN ACCENT

Accents are most often analysed during in-depth conversational speech. But did you know that your accent began developing before you could speak? Studies have shown that even in the first weeks of your life you already pick up some of the intonation of your native language and accent, mimicking these melodies when crying. Scientists believe that the first learnings of an accent take place while babies are still in the womb. What they hear during the months prior to being born impact their first sounds. During an experiment with 60 babies – 30 from French-speaking families and 30 German-speaking – researchers discovered that the rising and falling pitches in their cries matched the patterns of their native languages.

Crying babies can imitate speech rhythms and intonation

VOICES IN THE MIND

What role does the brain play in forming and controlling your accent?

Did you know?

Accent-free speech doesn't exist

1 LISTENING AND UNDERSTANDING
The brain is better at processing accents it's encountered. The ear conveys sound, but if the brain is unable to make sense of foreign sounds, it replaces them with those it understands.

2 WERNICKE'S AREA
Located behind your ear, Wernicke's area processes the sound of accents.

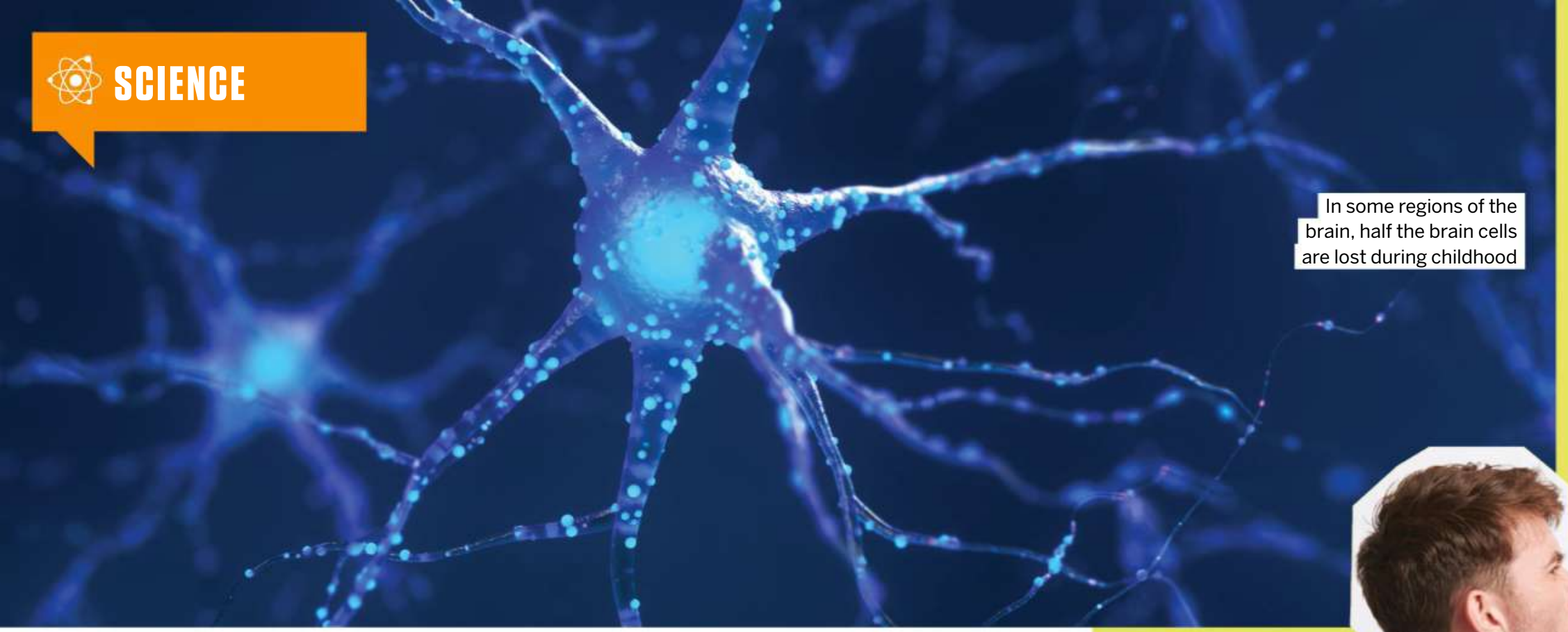
3 BROCA'S AREA
This region of the brain is most active just before you speak. Broca's area turns your brain's thoughts into sounds.

4 MOTOR CORTEX
After receiving the information from Broca's area, the motor cortex controls how your mouth moves. The shapes your lips, tongue and facial muscles make impact the sounds that leave your mouth.

5 CEREBELLUM
Details of how the back of the brain contributes to language are largely unknown, but the cerebellum impacts how we use separate syllables in speech.

6 A DIFFERENT ACCENT
When you put on an accent different to your own, an area deep inside the left side of your brain called the left anterior insula is activated.

© Getty



In some regions of the brain, half the brain cells are lost during childhood

WHAT IS BRAIN PLASTICITY?

For some people, moving to another country or region can cause their accent to change, but most of the sounds from your original accent are likely to remain permanent from around the age of 12. This is due to changes in brain plasticity. This is your brain's ability to adapt, modifying connections in the brain in response to the environment.

When you're born, your brain has the ability to develop any accent it's exposed to. But as you age, your brain becomes less flexible. You will keep your primary accent and won't pick up another language as easily – even when learning a second language and spending significant time using a new accent, you won't completely lose your original one. The purpose of brain plasticity is to stabilise new information once it's learned. Within the first year of your life, your ability to hear the sounds of different languages and accents diminishes. One study showed that Japanese babies were able to hear the difference between 'la' and 'ra' when they were six months old, but due to not being exposed to English speakers who used these sounds, Japanese babies aged between 10 and 12 months were unable to notice these same differences.

Did you know?

Sign language can also have different 'accents'

FOREIGN ACCENT SYNDROME: WAKING UP FOREIGN

Although extremely rare, it's possible for people to suddenly begin to speak with an accent they've never associated with. Since foreign accent syndrome was first recognised in 1907, there have only been around 100 cases of this happening. In these cases, people have complained of headaches or sustained injury to the head through strokes or other traumatic brain injuries before waking up with a new, foreign accent.

In 2015, Michelle Myers from Arizona went to sleep with what she described as "a blinding headache". When she woke up and spoke, she was surprised to hear a British accent in place of her usual American one. Although startling, this wasn't the first time it had happened to her. In previous instances, Myers had adopted Irish and Australian accents, but unlike her long-term British accent, these incidents only lasted a week. Scientists think that foreign accent syndrome changes people's pronunciation due to injury in Broca's area of the brain.

After 42 years with an American accent, Robin Jenks Vanderlip hit her head and now speaks with a Russian one

DID YOU KNOW? In 2010, an American woman woke up with a Russian accent after falling down the stairs

A map showing where common languages are spoken in different parts of the world

TEN ENGLISH-SPEAKING accents

How much can the same language vary when used around the world?

1 BRITISH ENGLISH

Language family: **Germanic** **Celtic**

A single 'British accent' doesn't exist, as pronunciation patterns have evolved differently by area. 'Received pronunciation', also known as Queen's English, is largely regarded as the UK's standard, despite only accounting for three per cent of the country.

2 AUSTRALIAN ENGLISH

Language family: **Australian aboriginal** **Germanic**

Australian accents don't have a strong 'r' sound at the end of words such as 'teacher'.

3 CANADIAN ENGLISH

Language family: **Germanic** **Amerindian** **Inuit-Aleut**

The vowel sounds made in Canadian accents are more nasal than other English accents, such as American English, which produce vowels at the back of the throat.

4 IRISH ENGLISH

Language family: **Germanic** **Celtic**

Many accents replace the 'th' sound in words such as 'three' with a single t, making it sound like 'tree'.

5 SINGAPOREAN ENGLISH

Language family: **Austronesian**

Accents include an extension of the last vowel sound in words. 'Th' is replaced with a 'd' sound .

6 NEW ZEALAND ENGLISH

Language family: **Germanic** **Austronesian**

The vowel sound 'e', such as in the word 'pen', usually sounds like an 'i', making the word sound like the British English word 'pin'.

7 INDIAN ENGLISH

Language family: **Indo-Aryan** **Dravidian**

Speakers shorten pronunciation of long vowel sounds, making 'don't' sound like 'dunt'.

8 AMERICAN ENGLISH

Language family: **Germanic** **Amerindian** **Inuit-Aleut**

Intonation is one of the key factors separating American English and British English. While British accents include mostly falling pitches, American accents often increase in pitch after the main stressed syllable.

9 SOUTH AFRICAN ENGLISH

Language family: **Niger-Congo** **Khoisan** **Germanic**

A common trait of some South African English accents is the 'a' sound being pronounced as 'eh' instead of 'ay'. For example, someone might say 'South Efrica'.

10 INTERNATIONAL ENGLISH

Language family: **N/A**

Due to there being so many variations of the English language, people who learn English as a second language can have unique and variable accents based on the resources they used to learn and distinguishing features of their own language.

© Getty / Eric Gaba

HOW DOES THE WORLD KEEP TIME?

Why the tick of timekeeping devices depends on hundreds of atomic oscillators positioned across the globe

WORDS
LAURA MEARS

DID YOU KNOW? The word ‘clock’ comes from the Latin for bell, clocca, because the first clocks struck bells

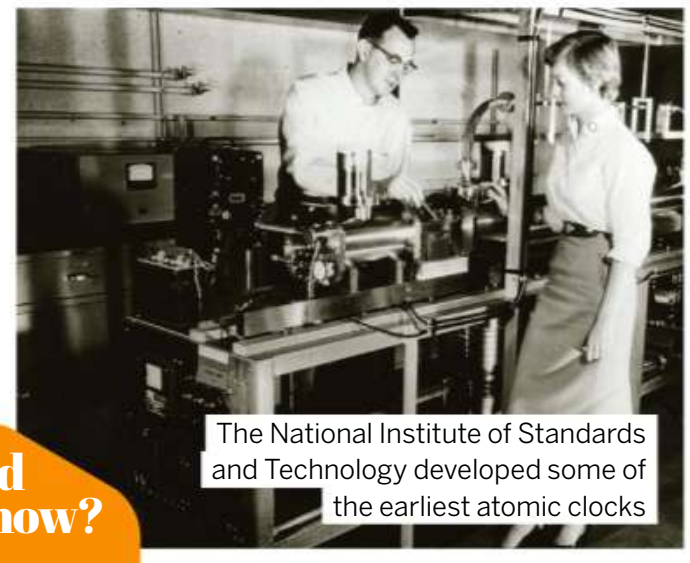
Have you ever wondered how the whole world stays in sync? We live in different time zones, but from New York to Melbourne, a second is always a second. That’s because everyone sets their local clocks using an internationally agreed standard called Coordinated Universal Time, also known as UTC. UTC is defined by an agency of the United Nations called the International Telecommunication Union. It’s based on two measurements: the ticking of hundreds of ultra-stable atomic clocks (International Atomic Time) and the rotation of the Earth (Universal Time).

Nations across the world set their local time by adding or subtracting from UTC depending on their position on the globe. UTC, or the world clock, has been around since the first day of the 1960s, shortly after Louis Essen built the first atomic clock. This precision timepiece promised to solve the centuries-old problem of second hands running too fast or too slow.

Before the 1950s, the most accurate clocks used vibrating quartz crystals to keep time, but the seconds would drift on a daily basis. Essen’s invention used the quantum properties of caesium atoms to keep the crystals in sync.

Now more than 400 extremely stable atomic clocks keep track of time the world over. Each one transmits a signal to the International Bureau of Weights and Measures in France. The bureau compares them once a month to come up with a final number called International Atomic Time. Each clock gets a different weighting in the calculation depending on how stable it is.

Atomic time is so precise that Earth itself can’t keep up. In theory our planet spins on its axis once every 24 hours, but in practice Earth’s rotation is slightly irregular. It fluctuates from day to day, and it’s gradually slowing down.


The National Institute of Standards and Technology developed some of the earliest atomic clocks

Did you know?

Shadows were used to track time in ancient Egypt

The irregularity in Earth’s spin means that International Atomic Time is now running 37 seconds fast. If we set our clocks by it, we’d soon be waking up for breakfast in the middle of the night. To account for this natural variation, the world clock also takes Earth’s rotation into account. The International Earth Rotation and Reference Systems Service (IERS) measure Earth time, known as Universal Time, by watching the stars race past as the planet spins. They then combine this with International Atomic Time to get a final figure for Coordinated Universal Time.

To prevent the atomic clocks running away with themselves as Earth’s rotation slows down, the IERS tries to keep Coordinated Universal Time and Universal Time to within 0.9 seconds of each other. This involves making regular adjustments called ‘leap seconds’. The first leap second was added in 1972, and there have been 26 more since. Some years there have been more than one, and in others there have been none at all. In 2020, Earth’s rotation actually sped up, making people wonder whether we’d need to remove a leap second for the first time.

This container holds the caesium atoms that power an atomic clock

BRIEF HISTORY OF TIME

Humans have been measuring time for tens of thousands of years. Since the dawn of our species, we have been using Earth’s rotation to keep track of the day, first by eye, and then with sundials. Our biggest challenge to begin with was being able to tell time in the dark, especially in the depths of winter when the days were short. Solutions included measuring the flow of sand or water, or tracking the length of a burning candle.

The first mechanical clocks didn’t appear until the Renaissance. They used weights to move wheels to strike bells to indicate the hours. Later inventors replaced gravity with springs and spinning wheels with swinging pendulums. In the 20th century, the first quartz clocks were invented, making way for atomic time.

Sundials, water clocks and sand timers are the oldest time-telling machines

© Getty / National Institute of Standards and Technology

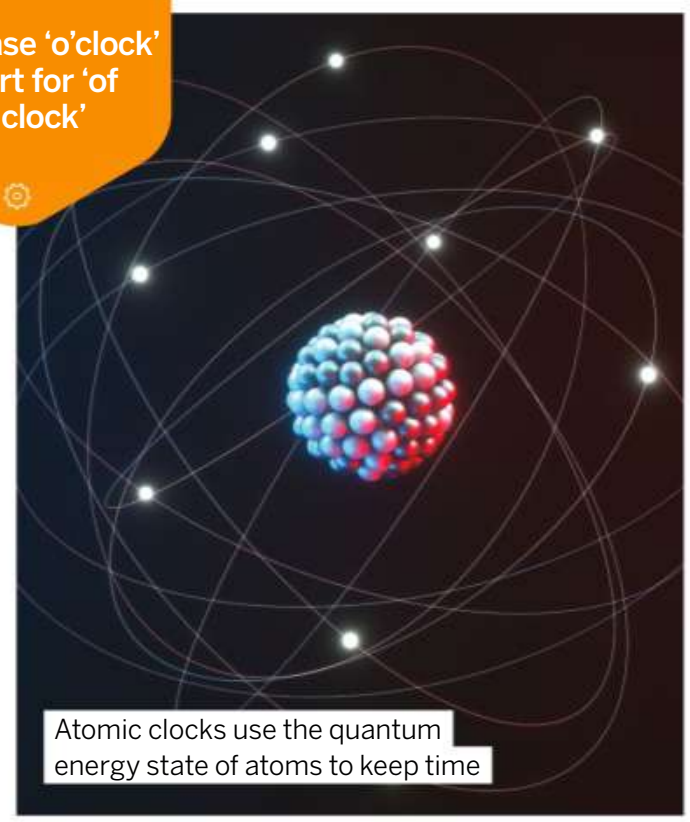
HOW ATOMIC CLOCKS WORK

Clocks use oscillators to keep time. These devices have periodic behaviour, swinging back and forth in a regular rhythm like a pendulum. The faster the swing, the more accurate the clock. The most common clock oscillator is a quartz crystal. It vibrates thousands of times a second, generating a wave that rocks up and down in a predictable pattern.

The trouble is, it's not completely stable. Time-critical tasks, like moving spacecraft, require clocks that can measure time to billionths of a second. Quartz clocks cannot provide that level of accuracy. To get around this, physicists have locked quartz crystals to the natural resonance of atoms. When exposed to precise frequencies, atoms change their energy state. Detecting these changes makes it possible to monitor the vibration of quartz crystals. When quartz clocks drift out of time, we can instantly correct them.

Did you know?

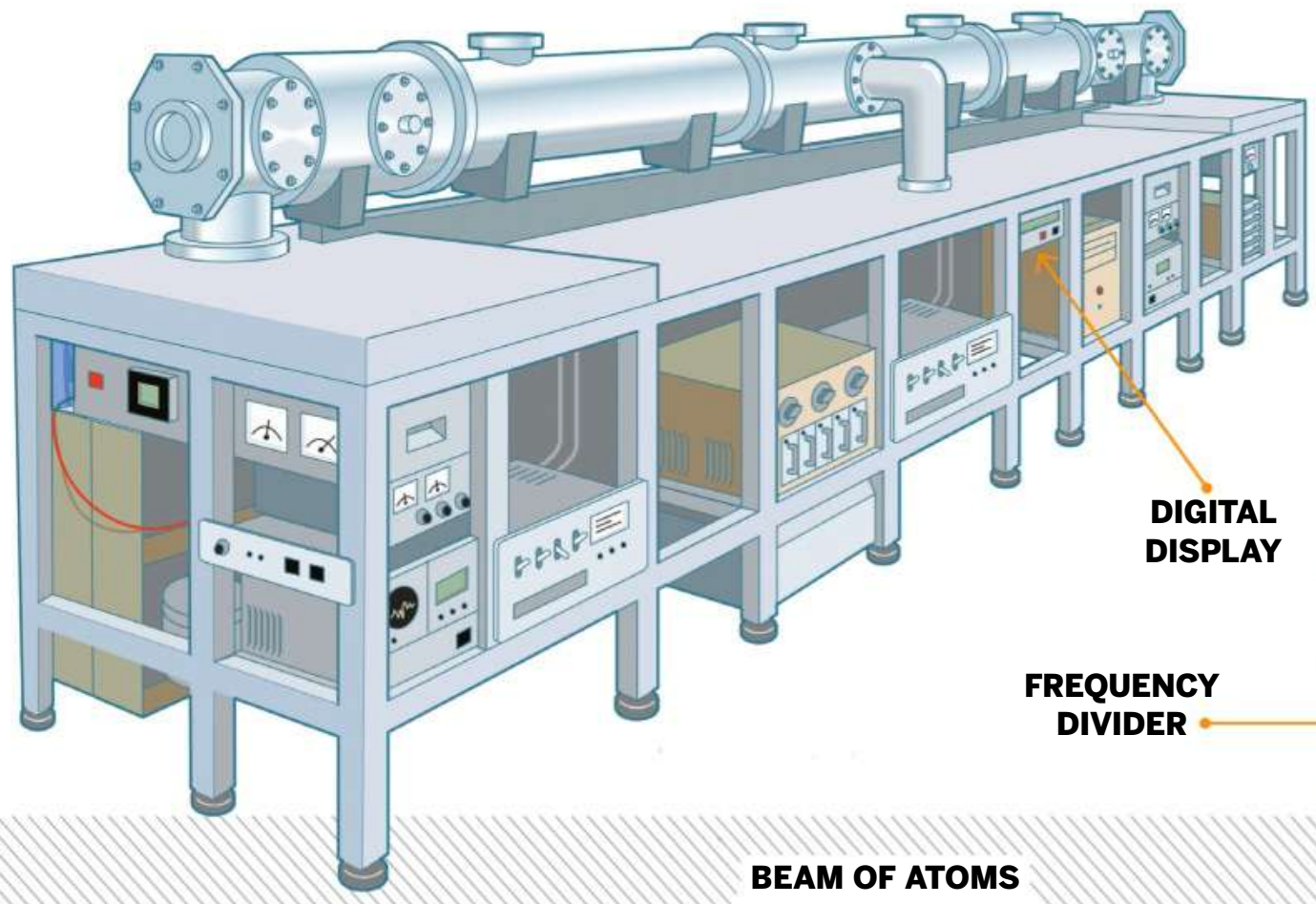
The phrase 'o'clock' is short for 'of the clock'



Atomic clocks use the quantum energy state of atoms to keep time

INSIDE AN ATOMIC CLOCK

When the frequency is just right, the electrons jump and the clock ticks



QUARTZ OSCILLATOR
To change the energy state of caesium atoms, the oscillator has to vibrate at a frequency of 9,192,631,770 Hertz (cycles per second).

DIGITAL DISPLAY

FREQUENCY DIVIDER

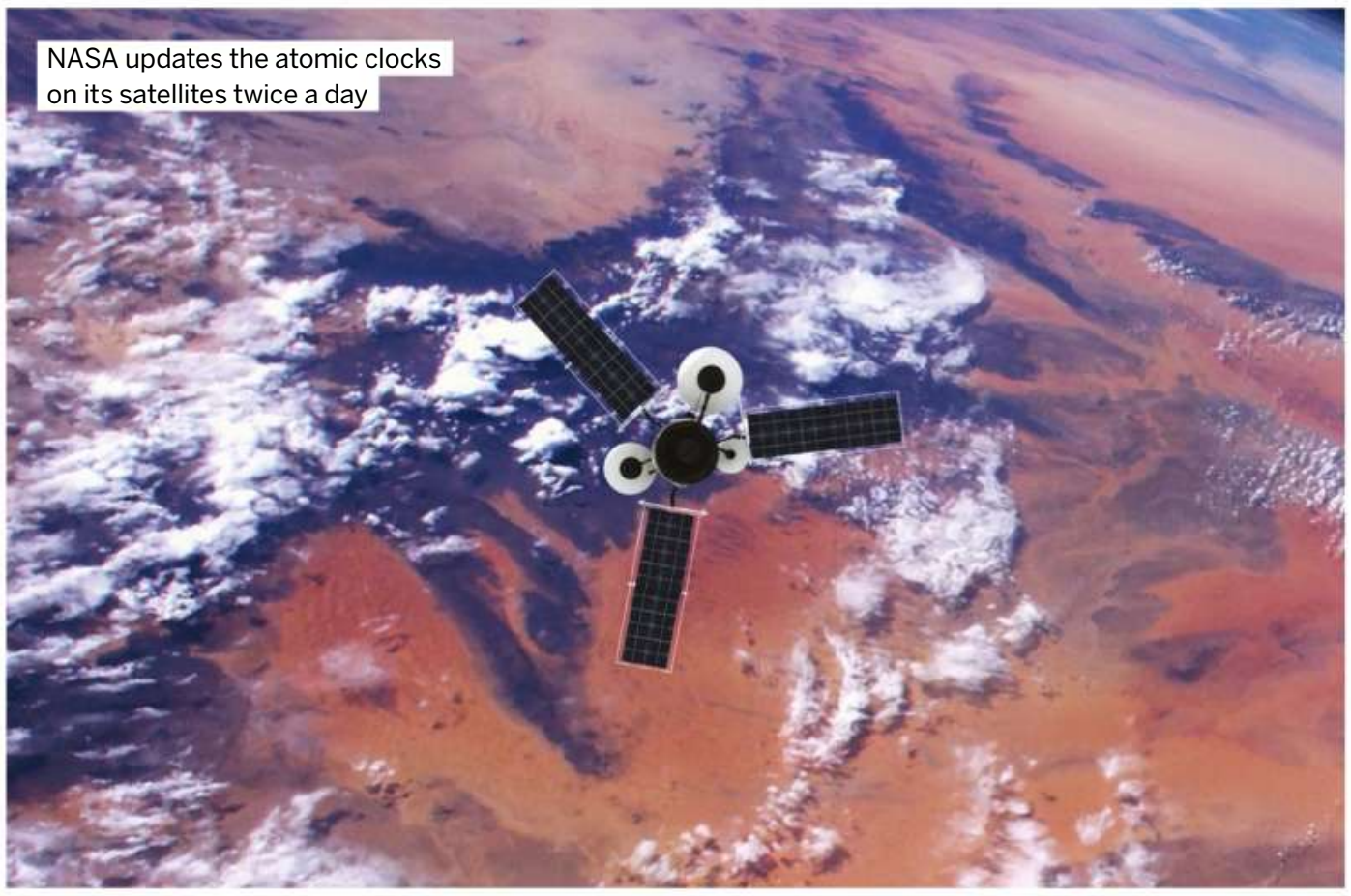
BEAM OF ATOMS
The hot atoms exit the oven with their nuclei and outer electrons spinning like magnetic tops.

CAESIUM OVEN
An oven heats caesium atoms to around 100 degrees Celsius.

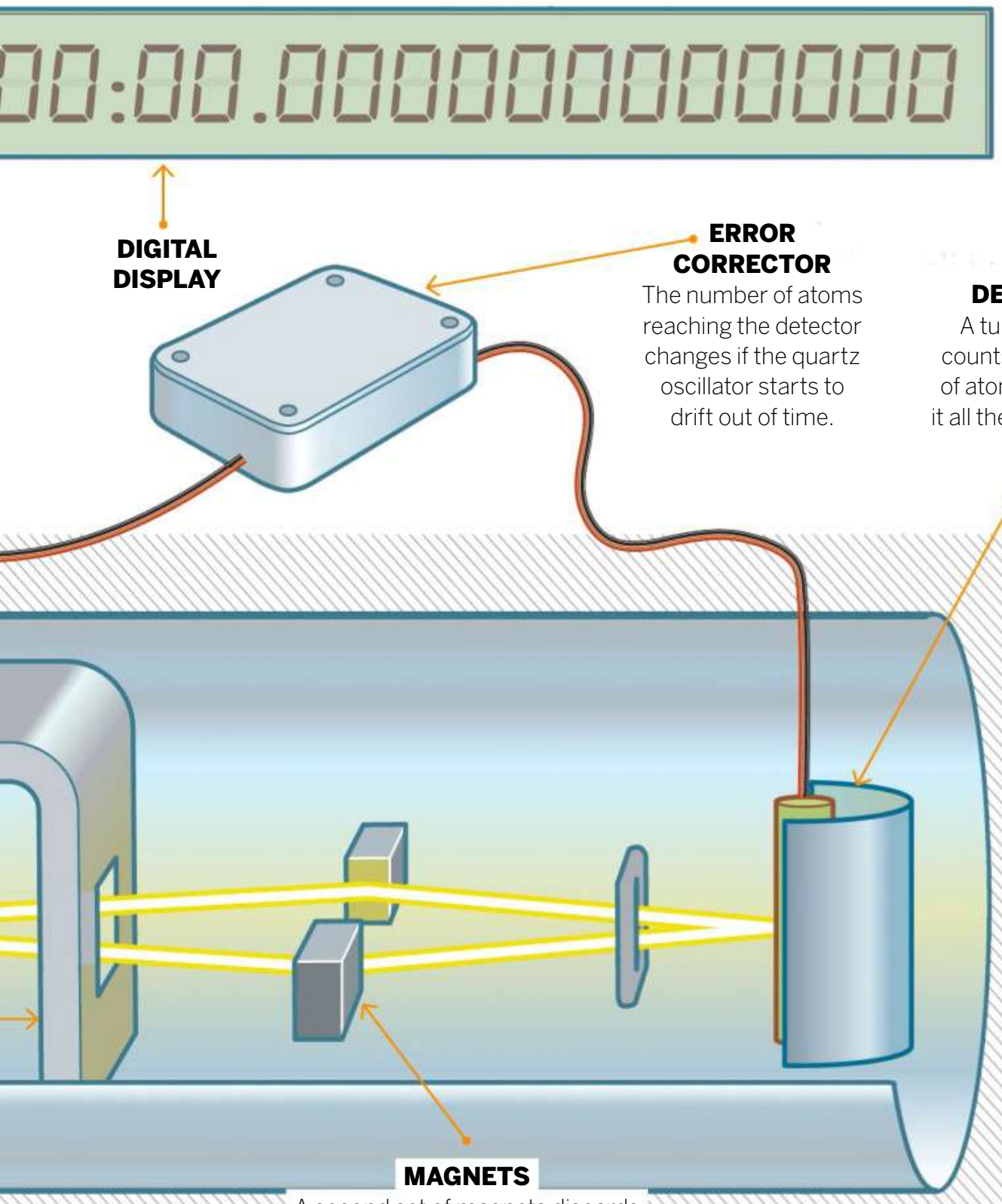
MAGNETS
A set of magnets choose the atoms that are spinning in the same direction.

MICROWAVE CAVITY
An oscillating field of microwaves switches the spin of the electrons, changing the energy state of the atoms.

DID YOU KNOW? Rubidium, mercury, strontium and hydrogen can also power an atomic clock



NASA updates the atomic clocks on its satellites twice a day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DIGITAL DISPLAY
ERROR CORRECTOR
The number of atoms reaching the detector changes if the quartz oscillator starts to drift out of time.
DETECTOR
A tungsten wire counts the number of atoms that make it all the way through.
MAGNETS
A second set of magnets discards any atoms that didn't change their spin in the microwave field.

CLOCK ACCURACY COMPARED

Earth's rotation
Accuracy: **A second lost every 1.5 years**
Invented: **4.5 billion years ago**

Pendulum
Accuracy: **A second lost every three hours**
Invented: **1657**

Marine chronometer
Accuracy: **A second lost every eight hours**
Invented: **1761**

Quartz
Accuracy: **A second lost every day**
Invented: **1927**

Atomic
Accuracy: **A second lost every 15 billion years**
Invented: **1949**

© Getty / Alamy / NASA / Wiki: Edvaldo LL Souza; Charles Frodsham; Tim Sheerman-Chase / National Institute of Standards and Technology

WHAT IS DUST?

Discover the ingredients that gather to form everyday household dust

WORDS **SCOTT DUTFIELD**

Did you know?

An average adult sheds 500 million skin cells daily

Dust accumulates around the house in a similar way to how a snowball rolling down a hill gathers snowflakes and builds into a large, icy sphere. Particles of dust, such as soil and pollen that float around in the air, become slightly positively or negatively charged. A positively charged dust particle will then be attracted to a nearby surface with the opposing negative charge, and vice versa for negatively charged dust particles.

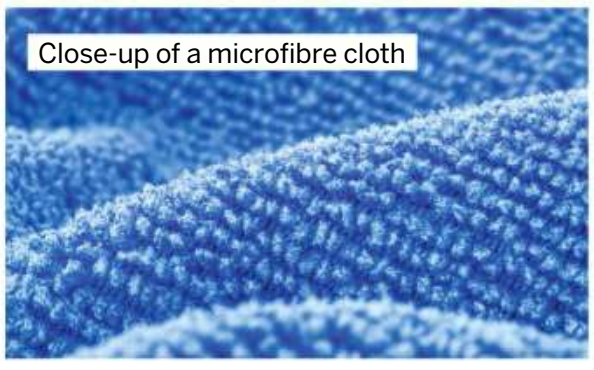
Over time, more and more dust particles bind together until they begin to form a visible layer of dust. On its journey to becoming a thick coating on the top shelf, dust gathers many ingredients from within and outside the house. Skin cells are thought of as the predominant ingredient for making dust. However, that's not quite the case. The composition of household dust can be divided into two parts. Around 60 per cent of what creates dust is produced inside the home, such as skin cells, hairs, food debris and fibres. The remaining 40 per cent is brought into a house from outside and includes materials such as soil and pollen.

There are also countless microbial communities that dwell among dust particles. Research has found that more than 20 genres of fungi and their reproductive spores – including penicillium – are commonly found in household dust along with between 500 and 1,000 different species of bacteria, including staphylococcus. Of course, different homes will have differing variations in microbial composition. For instance, studies have found farming homes contain larger microbial communities within their household dust than urban homes, and homes in tropical climates have less microbes in their dust than those in temperate climates.

MICROSCOPIC DINERS

Within the bundles of dust gathering on bookcases and hidden behind sofas are microscopic organisms called dust mites. Around a third of a millimetre in size, these tiny mites are well adapted to life among household dirt and feed on the many flakes of human skin within. Although they look like insects, they are eight-legged arthropods, making them more closely related to spiders. Though typically harmless, the dead bodies of the mites and the waste that they produce after a skin cell meal can cause allergic reactions among some people. Symptoms are comparable to those experienced by hay fever sufferers, such as sneezing, a runny nose and postnasal drip.

A artistic illustration of dust mites moving through fabric



Close-up of a microfibre cloth

DOWN WITH THAT DUSTER

When it comes to tackling household dust, there isn't a tool much better than a microfibre cloth – its invention in the 1980s put paid to feather dusters. These cloths are made from microscopic synthetic fibres that are 10 to 50 times thinner than a human hair, with each fibre being between three and five microns in diameter. A single cloth contains millions of these fibres, able to attach to and lift the tiniest of dust particles by using a weak electrostatic force called van der Waals force. This creates an attraction between the dust and cloth, causing the dust particles to latch onto the fibres, where they will remain until the cloth is heated during washing, where the fibre relaxes slightly and releases the dust.

DID YOU KNOW? The average household gathers around 18 kilograms of dust every year

DUSTY DETRITUS

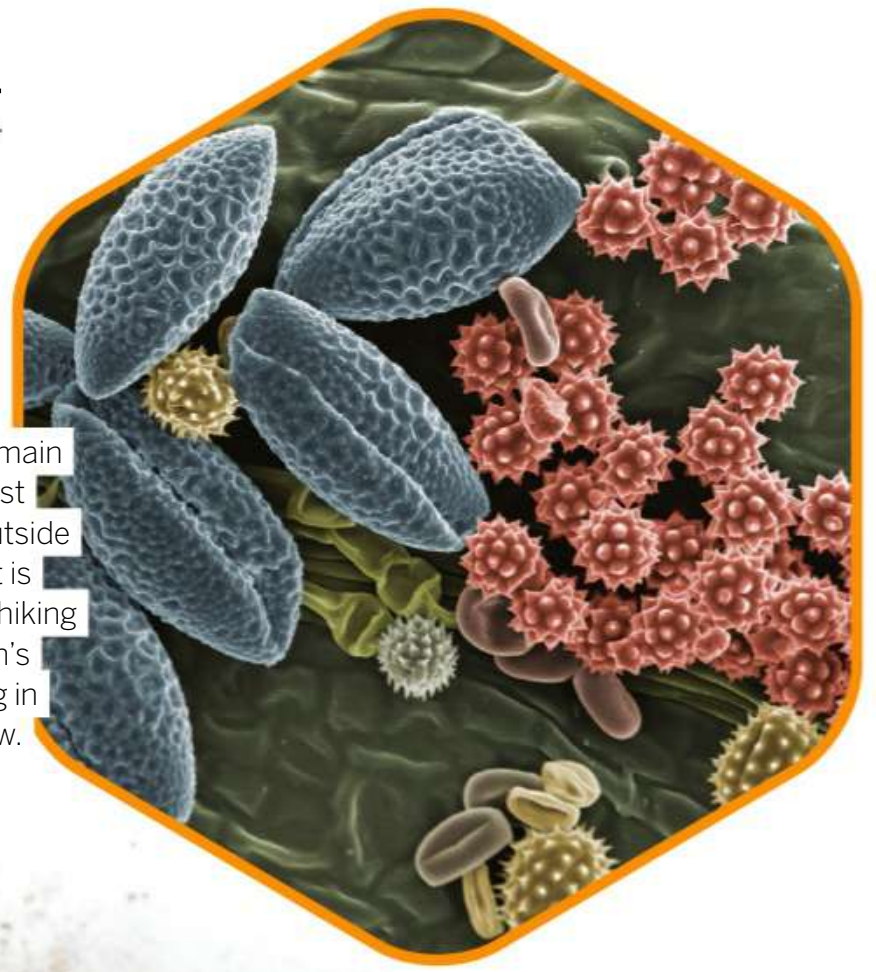
What goes into making household dust?

SKIN CELLS

It's a misconception that dust is mainly skin cells. Although humans shed a considerable amount of skin cells, the majority of the shed cells end up down the shower plug hole.

POLLEN

Pollen is one of the main ingredients of dust transported from outside into your home. It is either carried inside hiking a ride on a person's clothing or drifting in through a window.



PET DANDER

Flakes of your pet's skin, also known as dander, along with their fur or feathers will find their way into household dust.

INSECTS

The dead bodies of insects, such as cockroaches and moths, and their waste can contribute to the formation of dust.

SOIL

Similarly to pollen, soil can find its way into the home via the feet of those that walk through it.

FOOD DEBRIS

Crumbs down the side of the couch and other forgotten food particles dropped on the floor are a common contributor to dust formation.

© Getty / Alamy

Races take place globally using specially designed craft that have been modified for racing

JET SKI TECH

Jet skis are popular around the world, but how do these tiny boats go so fast?

WORDS **MIKE JENNINGS**

If you've ever been on a beach holiday, you'll have seen jet skis zooming around on the water. These lightning-quick boats look effortless and exciting, but plenty of hard work beneath the surface helps these pocket rockets bounce across the waves. You'd be forgiven for thinking that a jet ski operates with motors and propellers, but that's not the case – they work with powerful jets of water. And despite those jets, they're not actually called jet skis: that's a brand name that's become popular, just like how hoover is now a common term for vacuum cleaner. If you want to be accurate, call them personal watercraft.

Jet skis work thanks to a sleek system that relies on water and physics. A petrol engine powers an impeller which rotates inside a tube, and this sucks water into the ski and powers it out of a rear-facing nozzle at a higher speed. That speed increase gives the ski its forward momentum. The nozzle turns to allow riders to steer the ski, but the craft don't have any brakes.

The sheer popularity of personal watercraft means they're not just great tourist rental options. Personal watercraft races take place globally – the current world championship launched in 1996 – and jet skis are often used by lifeguards, police departments and navies. It's no surprise that they're used so widely: they're small, fast and manoeuvrable, and they're cheaper, safer and easier to use than many conventional boats. Today, personal watercraft are found in sit-down and stand-up designs, with the former more popular and the latter often only used by racers and stunt riders. Expect to shell out plenty of cash for one, too – a new jet ski costs at least £10,000 ($12,000).

THE JET SET

Personal watercraft work thanks to smart technology and basic physics

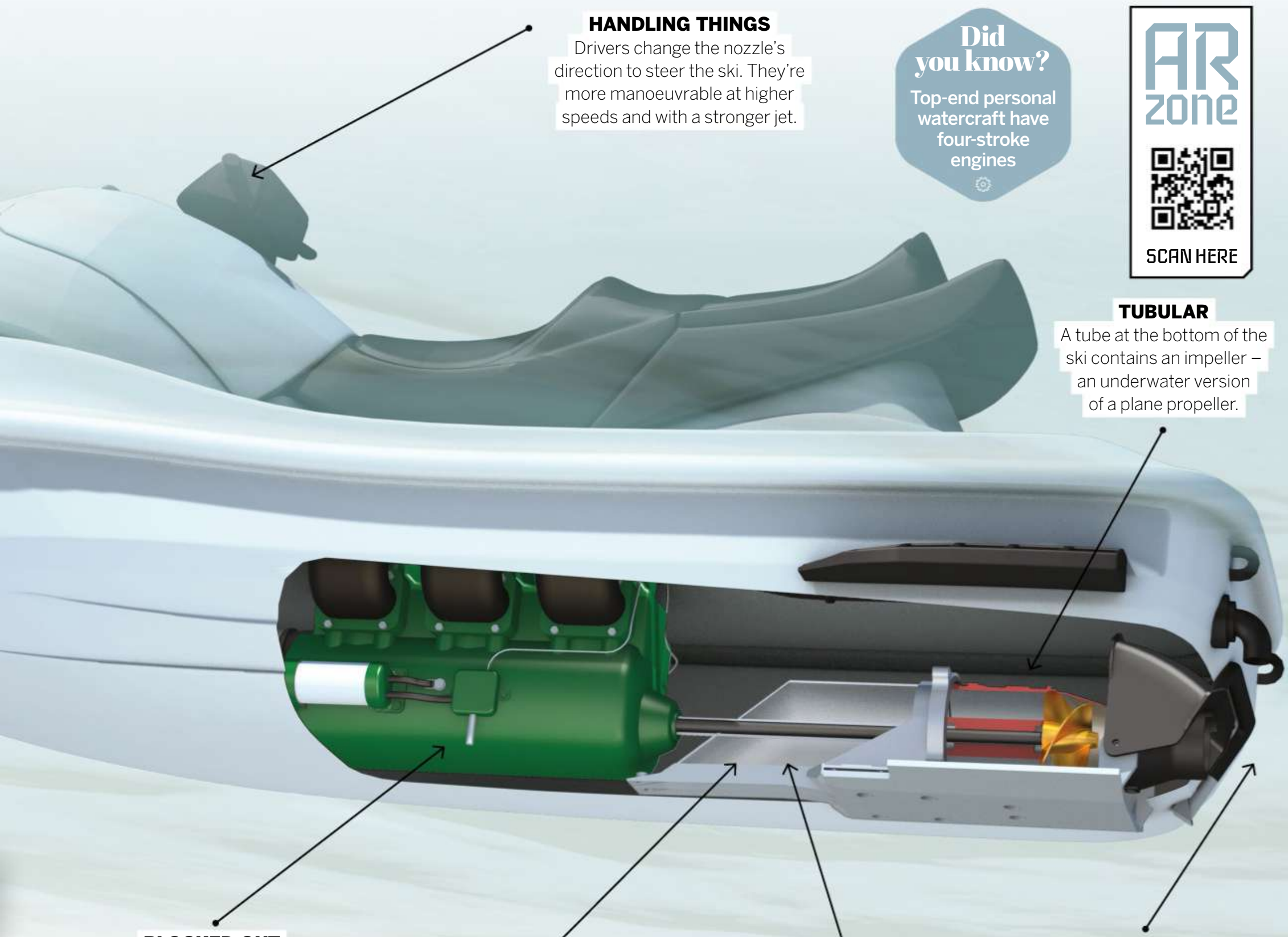
"These lightning-quick boats look effortless and exciting"

Futuristic jet skis will balance greener, eco-friendly designs with more luxury

JETTING TO THE FUTURE

Most personal watercraft still rely on petrol motors, so it's no surprise that tomorrow's jet skis will take a more environmentally conscious approach. Just like the motoring industry, the next wave of personal watercraft will use electric motors instead. Electric personal watercraft should still deliver loads of performance in a more eco-friendly package. Taiga's Orca hits 65 miles per hour thanks to a 180 brake horsepower electric drive system, and the reliance on electric hardware means you get instant torque and incredible acceleration, just like in electric cars. Because electronics and water don't mix, expect battery-powered personal watercraft to use robust, fully waterproof systems. Futuristic personal watercraft will also become more luxurious. Right now you'll find high-end models with Bluetooth connectivity, GPS systems and speakers, and next-generation devices will have 4K screens, better audio kits and reversing cameras. Some will even have Wi-Fi, sonar units, companion smartphone apps and their own operating systems.

DID YOU KNOW? Kawasaki sold more than 200,000 of its JS400 in 1973, starting a huge new trend for these versatile craft



HANDLING THINGS
Drivers change the nozzle's direction to steer the ski. They're more manoeuvrable at higher speeds and with a stronger jet.

Did you know?
Top-end personal watercraft have four-stroke engines

AR zone
SCAN HERE

TUBULAR
A tube at the bottom of the ski contains an impeller – an underwater version of a plane propeller.

BLOCKED OUT
The engine rotates the impeller, which sucks water into the ski, while a grate stops debris from entering the vehicle.

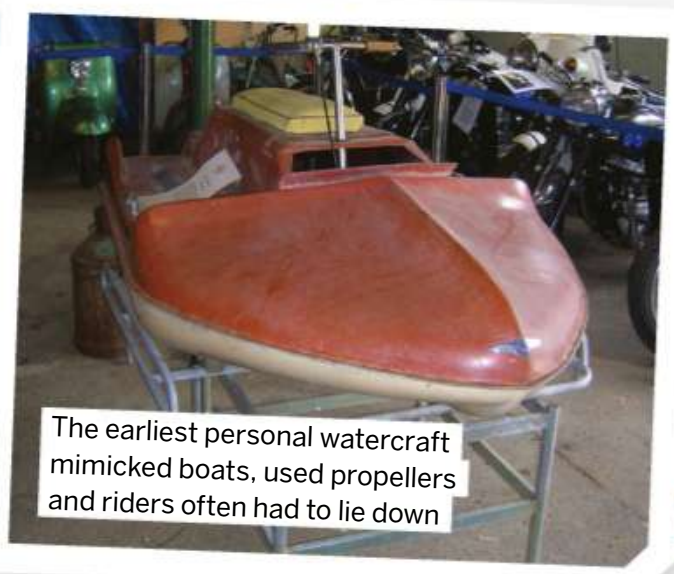
NO BRAKES
Riders can switch the drive shaft and impeller's direction, allowing the ski to reverse, but personal watercraft don't have brakes.

WATER POWER
The impeller's trio of blades suck water in, speed it up and propel it towards the pump at the rear.

NARROW OPENING
The rear nozzle is narrow, which increases pressure and speed – it's this speed increase that propels the ski forwards.

PERSONAL WATERCRAFT OF THE PAST

The term jet ski may have been launched by Kawasaki in 1972, but the first personal watercraft were called 'water scooters' and appeared in Europe in the 1950s. They used small outboard motors, and riders often needed to lay down to pilot these craft. By the 1960s, a Norwegian-American designer called Clayton Jacobson II invented the more familiar internal pump system, and Bombardier produced his designs – today the company still sells its Sea-Doo brand. Kawasaki's stand-up, single-rider jet skis arrived in the US in 1973, and sit-down models soon became more popular. Today pioneers like Kawasaki and Bombardier sell personal watercraft alongside Honda and Yamaha.



The earliest personal watercraft mimicked boats, used propellers and riders often had to lie down

© Wik: Meriden.triumph / Alamy / Getty / Illustration by Adrian Mann

CATERPILLAR TRACKS UNPACKED

Caterpillar tracks are found on tanks, tractors and loads of other tough vehicles; we go under the armour to find out how they work

WORDS **MIKE JENNINGS**

If you've seen a tank, a bulldozer or a digger, then you've seen caterpillar tracks in action. And while these systems look simple, there's a lot of technology, history and science behind their relentless march. Caterpillar tracks are sometimes called continuous tracks, and that name hints at how they work: it's one band of plates that never stops moving. There are a few important reasons why tanks have caterpillar tracks and why they're used on loads of other vehicles. For starters, tracks provide incredible traction on uneven, rough and slippery surfaces. They're far better than wheels because they've got a larger contact area, and they can reach places where wheels just can't go – even up sets of stairs or through ditches.

Did you know?

The biggest tank tracks use up to 100 plates

It's not just about that extra traction. Because of their larger surface area, tracks sometimes have less impact on the ground than wheels – perfect if you don't want enemies to see that a tank's been rolling through. They deliver power far more efficiently than wheels, and their sheer size means that tracked vehicles can support lots of weight. But it's not all good news. Trucks with tracks might get over virtually any obstacle, but they're not as quick or as manoeuvrable as vehicles on wheels. They're also trickier to manufacture and maintain, and therefore more expensive. Despite that, caterpillar tracks can be found in a variety of situations. Beyond tanks and construction trucks, you'll spot them on snowmobiles, certain types of tractors and even on wheelchairs.

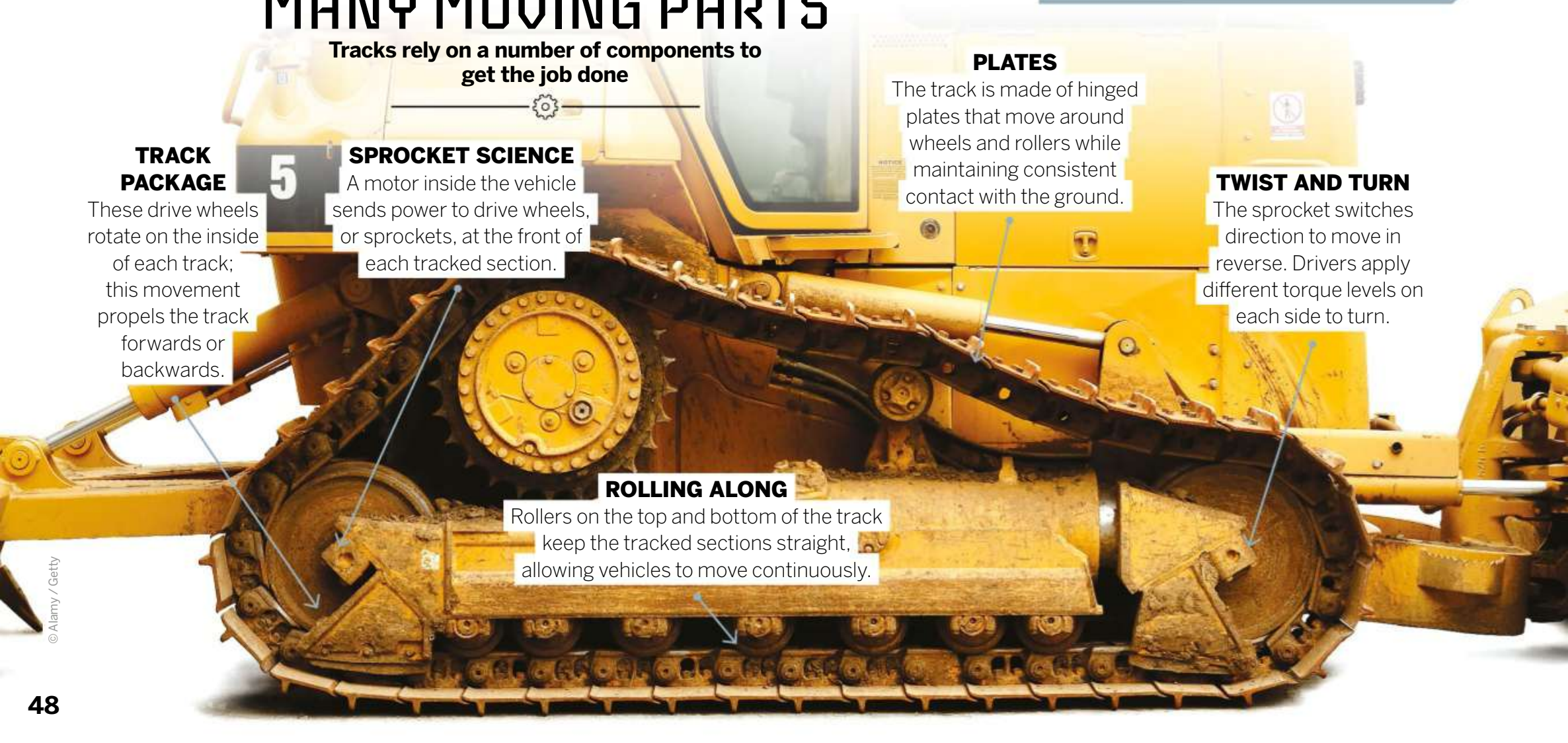
BACKTRACKING

Engineers in Poland, Russia and the UK all designed caterpillar-style systems in the 1820s and 1830s. People experimented with tractors, ploughs and trains with track-based movement. However, tracks didn't become commercially successful until they were deployed on a log-hauling machine in Maine in 1901. By 1905, continuous tracks were being used on tractors in the UK. Tracked vehicles were also used on an Antarctic expedition in 1910 because wheels didn't provide enough traction for moving on snow. Caterpillar tracks first appeared on British tanks in 1915, and they've been a military mainstay ever since – given difficult battlefield terrain and the sheer weight of combat hardware. Tanks with tracks can go places where wheels just can't reach, and they can carry more military equipment.

Tracks have been around for nearly 200 years – no surprise given their versatility

MANY MOVING PARTS

Tracks rely on a number of components to get the job done



5 TRACK PACKAGE
These drive wheels rotate on the inside of each track; this movement propels the track forwards or backwards.

SPROCKET SCIENCE
A motor inside the vehicle sends power to drive wheels, or sprockets, at the front of each tracked section.

PLATES
The track is made of hinged plates that move around wheels and rollers while maintaining consistent contact with the ground.

TWIST AND TURN
The sprocket switches direction to move in reverse. Drivers apply different torque levels on each side to turn.

ROLLING ALONG
Rollers on the top and bottom of the track keep the tracked sections straight, allowing vehicles to move continuously.

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THE STATUE OF LIBERTY

How one of the most iconic statues in the world was constructed

WORDS **SCOTT DUTFIELD**

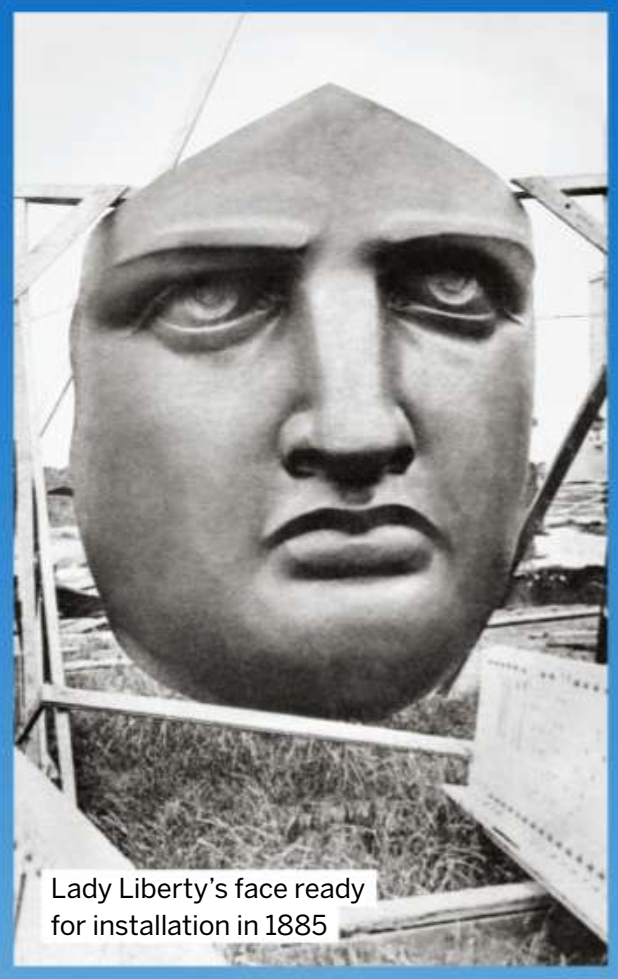
The Statue of Liberty has long been a symbol of freedom and hope. Its official title is *Liberty Enlightening the World*, named by its sculptor Frédéric Auguste Bartholdi. Also called Lady Liberty, the historic landmark was created to commemorate the centenary of the Declaration of Independence, along with America's close relationship with France, who gifted the statue in the late 1800s. The initial concept came from the French poet, author and activist Édouard René de Laboulaye. It's often reported that Laboulaye came up with the idea at a dinner party in 1865 following the assassination of Abraham Lincoln, but studies have found this to be false. Evidence suggests that Laboulaye conceptualised the statue between 1870 and 1871. The statue's creation also recognised the American ideals laid out in the Declaration of Independence following the end of the American Civil War and the abolishment of slavery. Lady Liberty has also been described as the 'Mother of Exiles' by the millions of immigrants that have turned to America for refuge.

Funding for the statue fell to both nations; the copper statue was financed by the French public through lotteries, entertainment events and public fees, whereas the stone pedestal on which it stands was funded by the US through theatrical events, auctions and a lucrative opportunity for donors to have their names printed in *The New York World* newspaper by the renowned Joseph Pulitzer.

In Paris her copper body was constructed in segments; in the US, Charles Pomeroy Stone was appointed engineer-in-chief for the construction of the pedestal. At a workshop in Paris, Bartholdi created a plaster cast of the Statue of Liberty around one-fourth the size of the final sculpture. Using his model, carpenters built wooden moulds around sections that would then be used to shape a single sheet of copper into a section of the final statue in a technique known as repoussé.

A sheet of thin copper was laid over the mould and hammered into the contours, recreating the shape of the study model in copper panels. It took 350 copper panels to complete. Beneath her copper skin is a network of iron frames that create the

DID YOU KNOW? The statue's copper is worth around £198,000 ($248,500) as scrap metal



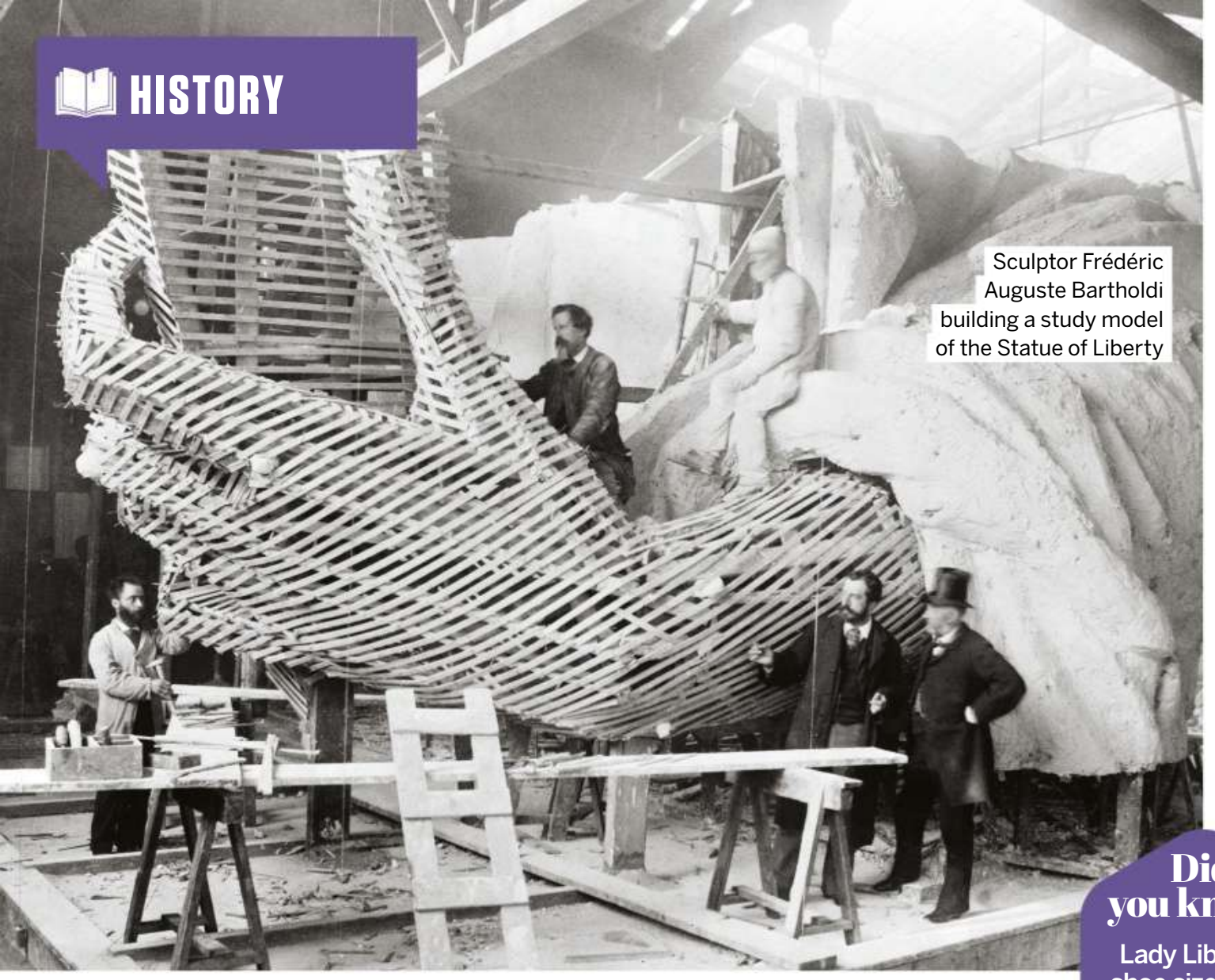
Lady Liberty's face ready for installation in 1885

Did you know?

The statue was transported to the US by ship in 214 wooden crates

In 1886, the Statue of Liberty was the tallest iron structure in the world

© Getty / Alamy



Sculptor Frédéric Auguste Bartholdi building a study model of the Statue of Liberty

skeleton. The internal metalwork was designed by French engineer Gustave Eiffel, who later constructed the eponymous tower. In the centre of the statue is an iron pylon, or 'spine', that runs from the base to the top and carries the entire weight. Each copper panel is connected to the iron skeleton via individual iron straps – this means that none of the copper panels bear the weight of the panel above.

Construction was completed in anatomical stages. The torch-wielding arm was finished in 1876, the head and shoulders by 1878 and the rest of the body by 1884. At this point, work on the stone pedestal in the US was underway. On a trip to the States in 1871, Bartholdi selected Bedloe's Island – now known as Liberty Island – as the site for the statue, visible from New York Harbour to be seen as the 'gateway to America'. He decided the structure would sit in the centre of Fort Wood, an 11-point-star-shaped fort built in the 19th century. The already-bomb-proof fort was strengthened with concrete to bear the weight of the granite and concrete pedestal.

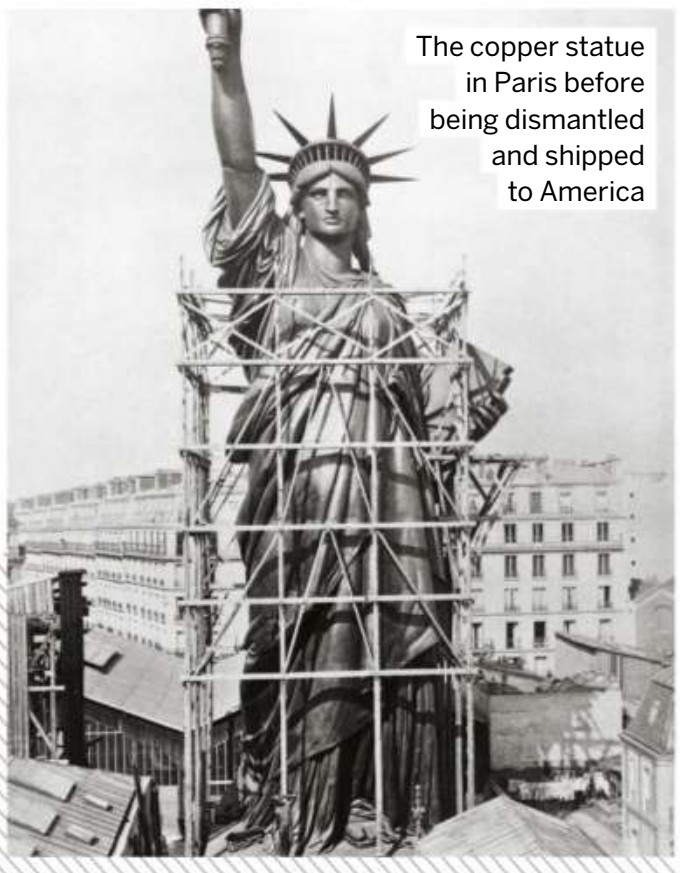
Once the pedestal was built, the copper sculpture could be reconstructed and mounted on top. The statue reached New York Harbour in 1885, having travelled more than 5,000 miles across the Atlantic Ocean aboard a French Navy ship. It was transported disassembled, ready for reconstruction once the pedestal was completed in 1886. Only a few months after the pedestal's completion, the statue was erected, unveiled to the world the same year. People came from far and wide to visit the copper beacon of freedom, but by 1920 visitors of the once-copper giant were greeted by the blue-green coating.

The colour transformation is the result of a chemical process called patination, whereby a layer of patina forms on top of the copper when it is exposed to the air. Over three decades the copper has gone through a series of oxidation reactions, where an element loses electrons in chemical reactions. In the first few months of standing in the open air, the copper panels reacted to oxygen in the atmosphere, forming a reddish mineral called cuprite. After a year or two, the statue became dark brown as cuprite further oxidised to form a black mineral called tenorite. After around three to four years the Statue of Liberty would have been a much darker brown colour thanks to the build up of tenorite.

As human activity increased within New York City, so did the emission of a pollutant called sulphur dioxide. Once in the atmosphere, sulphur dioxide mixed with water and rained down on the statue, causing a chemical reaction with the

Did you know?

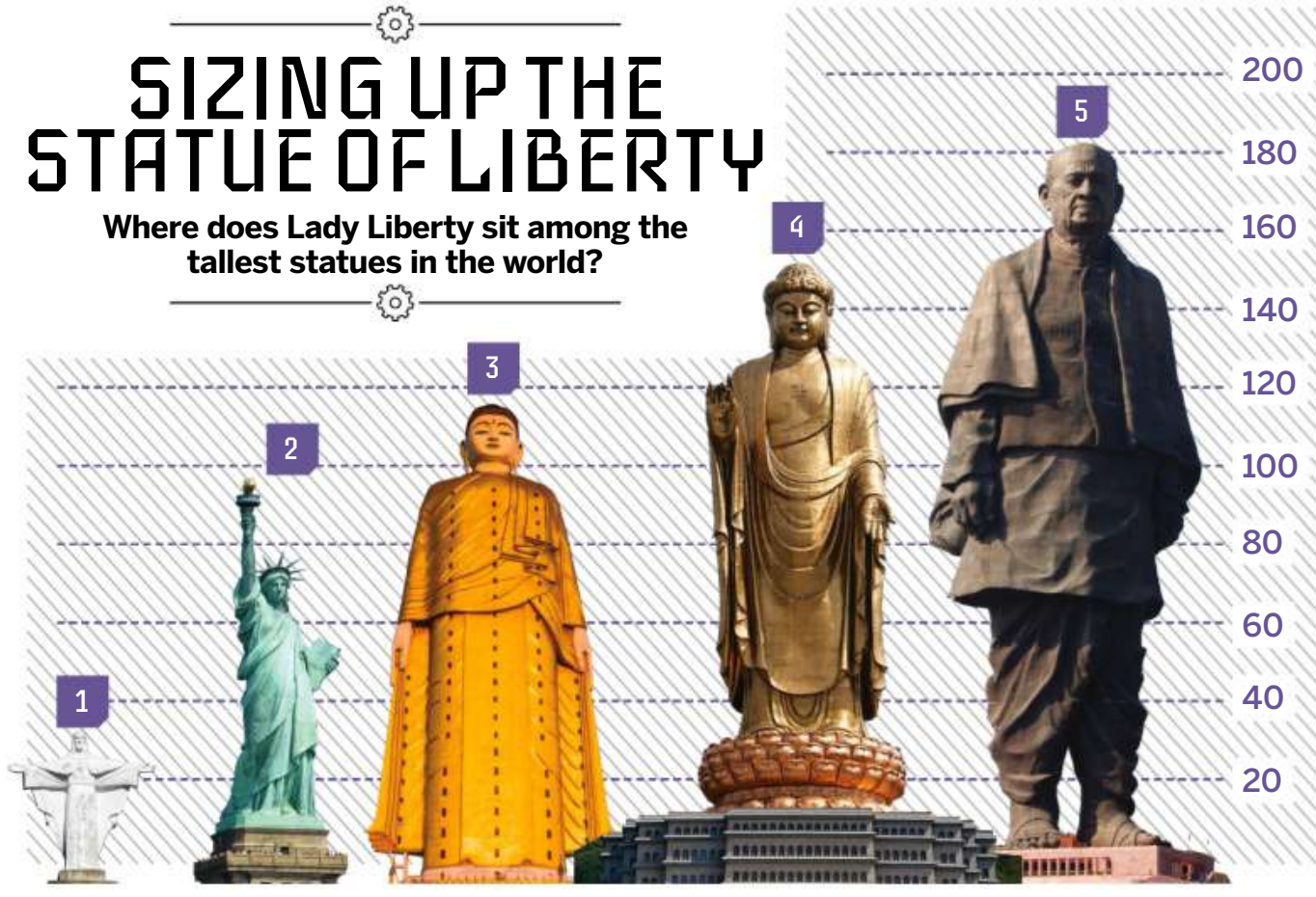
Lady Liberty's shoe size is 879



The copper statue in Paris before being dismantled and shipped to America

SIZING UP THE STATUE OF LIBERTY

Where does Lady Liberty sit among the tallest statues in the world?



1 CHRIST THE REDEEMER
Country: **Brazil** Height: **30 metres**

2 THE STATUE OF LIBERTY
Country: **US** Height: **93 metres**

3 THE LAYKYUN SEKKYA BUDDHA
Country: **Myanmar** Height: **116 metres**

4 THE SPRING TEMPLE BUDDHA
Country: **China** Height: **153 metres**

5 THE STATUE OF UNITY
Country: **India** Height: **182 metres**

DID YOU KNOW? The amount of copper used to build the statue could make 435 million one-cent coins

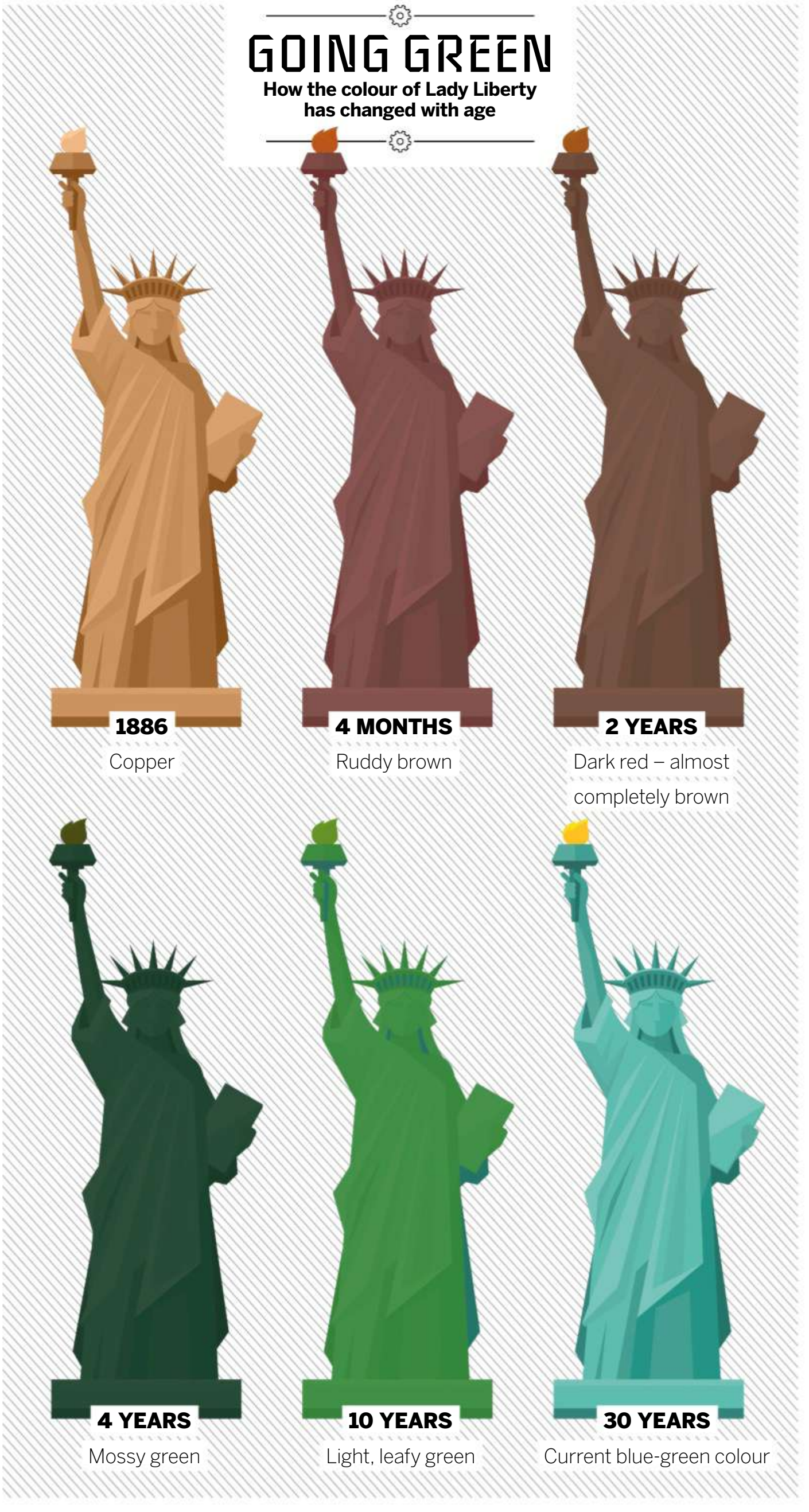
tenorite and creating a green mineral called brochantite. As more brochantite became exposed to sulphur dioxide, it became a greener mineral called antlerite. In addition, sprays of chloride from the nearby ocean created patches of green atacamite in places where the rain couldn't wash it off.

The original copper isn't completely lost. The patina coating works as a protective layer – now almost as thick as the copper walls themselves – and prevents the metal beneath from eroding. However, the same can't be said for her iron skeleton. In 1984 restoration missions were carried out to repair holes and replace rusting iron bars with stainless-steel alternatives. Two years later the restorations were complete, along with a new illuminating flame for all who ventured near the harbour to see.

A NEW FLAME

The torch is one of the statue's most recognisable elements, but the current flames are not those installed in 1886. Bartholdi's design called for a copper flame coated in a layer of gold leaf, illuminated by a series of lights around the balcony to bring the flames to life. Unfortunately, Bartholdi's ideas for the torch were abandoned due to fears its bright light might blind passing pilots. After exploring several options for how the torch should be built and used – it was even proposed that the statue could be utilised as a lighthouse at one time – it was created out of multiple panes of glass with a bright bulb within. In 1984 enthusiasm for Bartholdi's original designs was re-ignited following restorations, and the torch was replaced with a 24-karat-coated flame illuminated by a ring of floodlights. The statue's original torch now sits inside the Statue of Liberty Museum.

The original torch on display in the Statue of Liberty Museum



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INSIDE THE STATUE OF LIBERTY

Take a tour of *Liberty Enlightening the World*

CROWN
The seven spikes emerging from the statue's crown represent the seven seas and seven continents of the world.

A MOTHER'S FACE
The statue's face is thought to be modelled after Bartholdi's mother.

COPPER SKIN
The statue is made up of 300 sheets of coin-thin copper.

IRON SPINE
Four iron columns support the statue's framework.

COLOUR CHANGE
Over 30 years the copper statue developed a blue-green patina.

THE WEIGHT OF LIBERTY
The copper in the statue weighs 27.2 tonnes. The skeleton adds 113 tonnes, all sitting on a 24,500-tonne stone pedestal.

DECLARATION OF INDEPENDENCE
The tablet's inscription reads 4 July 1776 in Roman numerals, corresponding to the date the Declaration of Independence was adopted.

BROKEN SHACKLES
Bartholdi included a set of broken chains at the statue's feet to symbolise the end of slavery in America.

Did you know?
3.5 million people visit the statue each year
MANY DIFFERENT HAMMERS
300 different types of hammer were used to shape the statue's copper panelling.
DUAL STAIRCASES
Two adjacent staircases spiral around one another – one used to ascend and the other for visitors to descend.
CONSTRUCTION
It took nine years to build the statue in France and a further four months to reassemble it after it was delivered to the United States.
BIG PRICE TAG
Building the statue and pedestal cost around £8 million ($10 million) in today's money.
AR zone
SCAN HERE

© Illustration by nicholas Forder

DID YOU KNOW?

In 1906, US Congress considered painting over the statue's green patina

THE COMMONWEALTH GAMES

How will the 2022 games compare in nearly 100 years of this huge sporting event?

WORDS AILSA HARVEY

Every four years, top athletes from the world's Commonwealth countries take part in one of the largest international sporting competitions in the world. The multi-sport event has changed its name since it was first introduced over 90 years ago as the British Empire Games. Today the Commonwealth Games aims to better celebrate the many unique nations that compete, bringing together their most elite athletes.

Until 1998 the Commonwealth Games only held individual events, but today it includes sports such as cricket, netball, rugby and hockey. In more recent years the games has also developed more inclusive programs, with para-sport events for disabled athletes. The 2022 event is the 22nd Commonwealth Games to take place after the 1942 and 1946 games were prevented by World War II. Following the route of the games' baton – a pre-event relay that connects all the Commonwealth countries – How It Works explores some of the nations competing in 2022 and the history of these games.

Did you know?

The 2022 Queen's Baton Relay lasts 294 days

1 LONDON LAUNCH

Queen Elizabeth launched the baton relay at Buckingham Palace on 7 October 2021. She first attended the games in 1970.

2 FIRST OF 19

The first baton stop of Africa's 19 Commonwealth countries was in Nigeria on 16 October. It spent two days being passed through Nigeria, being used as part of dances to display Nigerian culture.

3 CHRISTMAS EVE ON THE ISLANDS

From 22 to 24 December, the Queen's Baton toured the Seychelles. This country of islands is divided into 26 districts. During their time in the spotlight, children from each one shared untold stories about their district.

4 REVISITING A PREVIOUS HOST

The first point of call when the baton began its four days in India on 12 January was New Delhi. In 2010 the city hosted around 6,572 athletes for the Commonwealth Games. Following the Kuala Lumpur 1998 games, this was the second time Asia hosted.

5 PASSING THE TIMEKEEPER

The Commonwealth Games has an official timekeeper to record the data of thousands of athletes as they compete. During the relay, Longines – a watchmaking company and 2022 timekeeper – was paid a visit in Singapore.

9 MULTI-HOST

On 26 May the baton stopped in Canada for four days. Canada is one of only six countries to have competed in every Commonwealth Games, and has hosted four times.

10 LAST STOPS

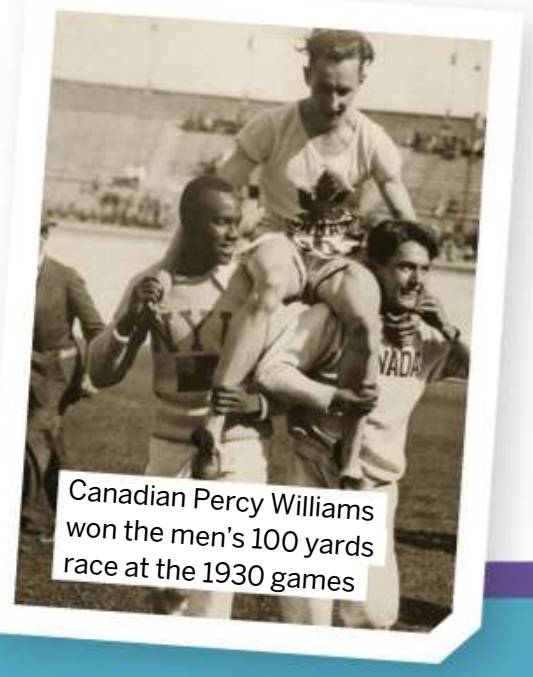
After visiting Jersey, Guernsey and the Isle of Man, the baton returned to the UK. Eventually the baton will be delivered to the opening ceremony in Birmingham. Inside the baton is a message from the queen which has been carried around the Commonwealth.

Luvo Manyonga of South Africa set a Commonwealth Games long jump record of 8.41 metres at the 2018 games

DID YOU KNOW? Australia is the most successful Commonwealth Games nation, having won 932 gold medals and 2,416 medals in total

HOW DID THE GAMES BEGIN?

The event first emerged as a way to bring together the nations of the British Empire. Although this idea was considered in the 1890s, the first games weren't held until 1930 in Hamilton, Canada. Only 11 nations competed, compared to 72 in 2022. The 11 nations were Australia, Bermuda, British Guyana, Canada, England, Northern Ireland, Newfoundland, New Zealand, Scotland, South Africa and Wales. 400 athletes competed in the six sports available, with Canadian triple jumper Gordon Smallacombe winning the first Commonwealth gold medal. Aside from athletics, the other sports of the first games were boxing, lawn bowls, rowing, swimming, diving and wrestling. Women were only allowed to compete in the aquatic events.



Canadian Percy Williams won the men's 100 yards race at the 1930 games

WHAT TO EXPECT

The 2022 Commonwealth Games in Birmingham begins on 28 July and finishes on 8 August. During these 11 days there are around 300 separate sports sessions scheduled and more than 5,000 athletes due to attend. Unlike any other Commonwealth Games, the 2022 games has more medal events for women than for men. Some of the sports being played are new additions for the Birmingham event, including basketball 3x3, wheelchair basketball 3x3 and women's cricket. The impact on host communities and the environment have always been controversial at such large-scale sporting events. However, the Birmingham 2022 Games aims to be the first carbon-neutral Commonwealth Games. Free public transport will be available during these days, 2,022 acres of forest are being planted across the West Midlands and organisers aim to send no waste to landfill sites.

The 2022 Queen's Baton is the most advanced yet

6 WELCOMING 2022
On New Year's Day 2022, the year of the Commonwealth Games began with the baton in the Maldives. The Maldives left the Commonwealth in 2016, but rejoined in 2020.

7 THE SMALLEST ISLAND NATION
The baton arrived in Nauru on 5 February – the smallest Commonwealth country with a population of 10,000. This part of the relay involved a tour of Nauru Museum to share knowledge of the country's original tribes.

8 DOWN UNDER
Between 12 and 20 March the baton toured New Zealand and Australia. The baton returned to the Gold Coast, where the previous games were held.

FOLLOW THE QUEEN'S BATON

The 16th baton relay visits all 72 of the Commonwealth nations to celebrate their cultures and unite them

The gold medal design for the 2022 Commonwealth Games

© Getty / Library and Archives Canada

GREGOR MENDEL

This Austrian scientist is known as the ‘father of modern genetics’

WORDS **AILSA HARVEY**

Mendel combined his science expertise and experience of working as a gardener to unravel the basic principles of how you became you. Your genes are sequences of DNA passed from your parents onto you, determining all of your inherited traits. In the 19th century, the process of inheriting curly hair, a specific blood type or eye colour was thought to be caused by a merging of both of your parent’s genes.

Mendel – who spent eight years isolating each of a pea plant’s traits and pollinating them in different sequences – discovered many of the main rules of genetics. He revealed that each trait an individual has is made up of two units – one from each parent. One of these holds more power than the other and will be responsible for displaying that specific trait. This could be brown eyes over blue eyes, for example. In this case, the gene for brown eyes is dominant and the blue-eye gene is recessive. Mendel discovered that although the gene for blue eyes might not be visible in features, it still exists at a molecular level and can re-emerge in later generations.

Mendel was born into a family with very little money, which became difficult when he sought an education for his scientific interests. When he first left his home in Heinzendorf bei Odrau, then in Austria, to study, his family were unable to support him. Mendel tutored other students as well as pursuing his own studies in order to earn enough money to live. During his early education, he suffered from depression and was forced to return home because of this. During this time, he discovered the religious community at the monastery, which included a highly intellectual group. Becoming a monk meant that his ongoing education was funded, and this new diverse community allowed him to explore his experimental nature.

Did you know?
Mendel’s birthplace is now a museum

Mendel had many changes in his career, social circles and even his name. Becoming known as the father of genetics wasn’t in his original plan. His paper on pea plants, titled *Experiments on Plant Hybrids*, was published in the Natural Science Society’s journal in 1865, but had little impact at the time. Today Mendel is considered a great success, and his work is essential knowledge for scientists working in gene discovery and inheritance.

Above: This is the monastery in Brno, Czech Republic, where Mendel carried out his genetic experiments

Right: Mendel’s work went largely unrecognised during his lifetime

Right inset: This manuscript about genetics was handwritten by Mendel in 1865

5 THINGS TO KNOW ABOUT GREGOR MENDEL

1 YOUNG STUDENT
A priest persuaded Mendel’s parents to send him to school early after witnessing his academic ability.

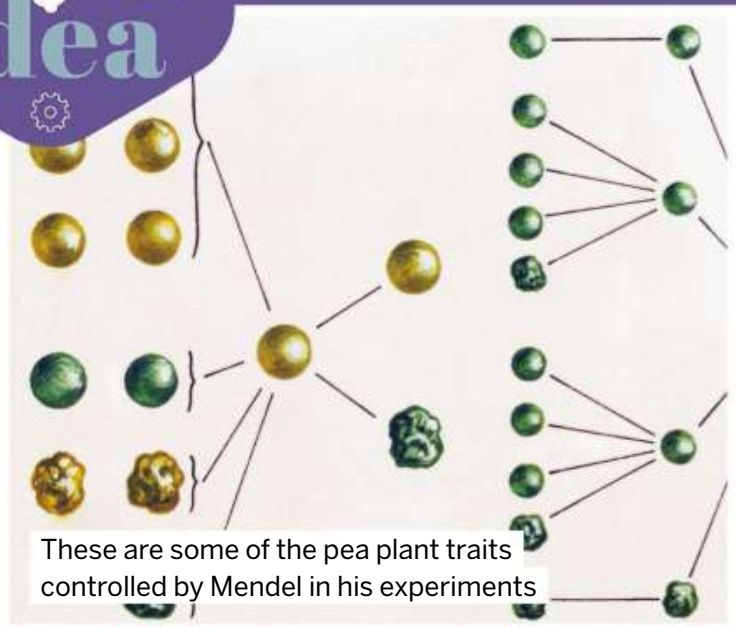
2 TEACHING HOPES
Mendel sat the exam to become a qualified high school teacher twice. He failed both times.

3 HOMETOWN
The village where Mendel was born is today part of the Czech Republic.

4 FAMILY TRADITION
During his youth, Mendel worked on a farm which had belonged to his family for at least 130 years.

5 LOST WORK
The results of Mendel’s experiments on honeybees and hawkweeds were lost.

The BIG idea

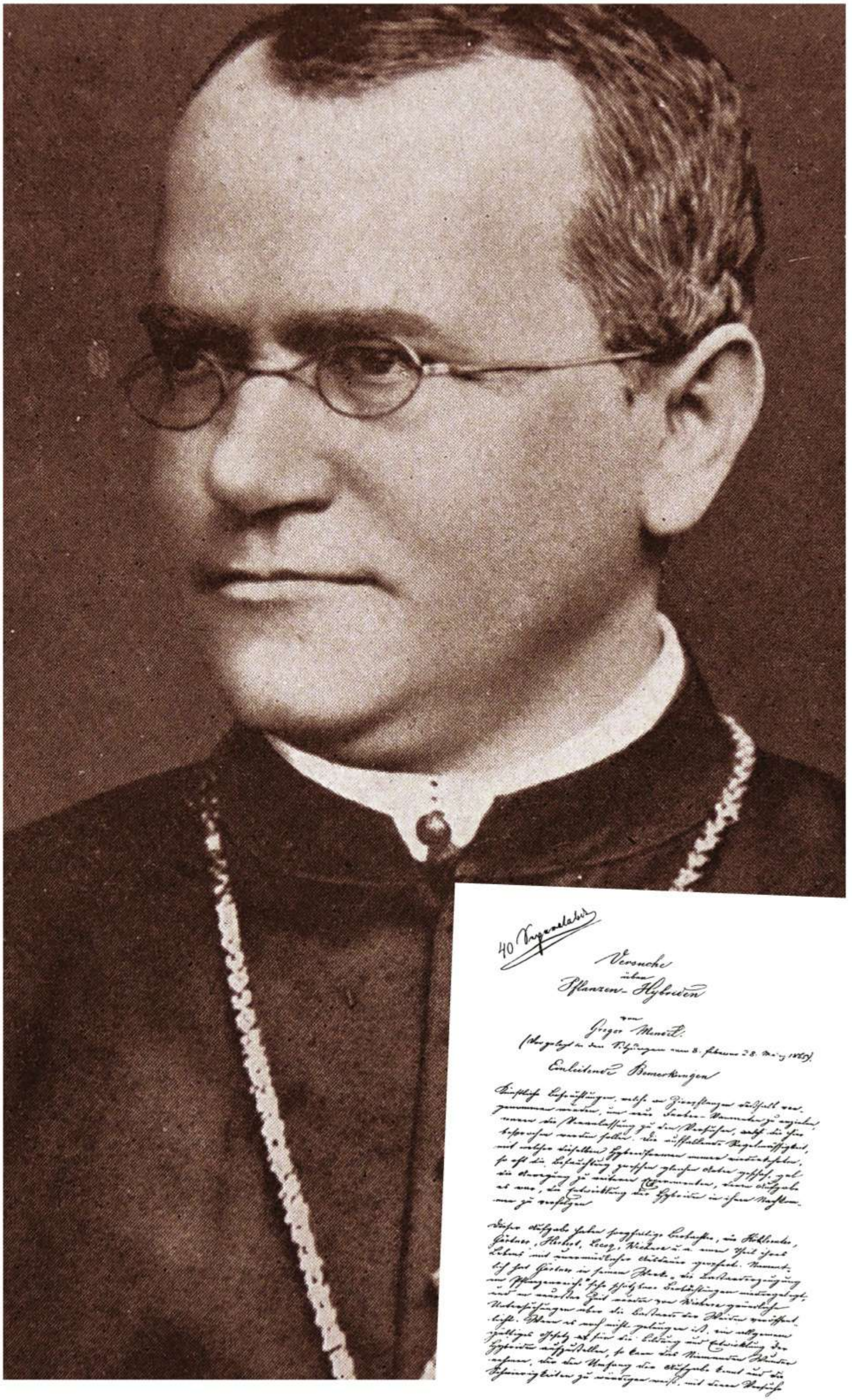


These are some of the pea plant traits controlled by Mendel in his experiments

MENDEL’S LAWS OF INHERITANCE

Mendel’s analysis of 34 pea plant subspecies to determine how and when traits are passed down from parents to offspring is his most famous work. He studied pea plants (*Pisum sativum*) because they have many variations. Also, each plant has both a stamen and stigma – the male and female reproductive parts of a plant. Having both means that the pea plant can self-pollinate or cross-pollinate.

To experiment with different variations of genetics, Mendel cross-pollinated some of the pea plants. This meant transferring the pollen of one plant, containing male reproductive cells, onto the stigma of another. As part of his experiments he studied seven traits, such as the shape and colour of flowers and seeds. When the parents of one plant had two separate flower colours, only one colour was present in the offspring. But when the offspring self-pollinated, the trait that didn’t present in them could appear in their offspring. Mendel discovered this was made possible by recessive genes. He proposed that only dominant genes were visible in the offspring, but that recessive genes could be passed through generations.



Versuche über Pflanzen-Hybriden

Gregor Mendel

A LIFE'S WORK

The monk who turned to pea plants

1822

On 20 July, Mendel was born as Johann Mendel in the rural village of Heinzendorf.

1833

Mendel left home to go to grammar school at the age of 11.

1840

Mendel began a two-year course in philosophy.

1843

Mendel became a monk at St Thomas' Abbey in Brno, changing his name to Gregor.

1849

Mendel became a substitute teacher in Znojmo.

1850

Mendel was sent to the University of Vienna to prepare for his second teaching exam.

1854

Mendel failed to become a teacher, but began his studies of pea plants under permission of Abbot Cyril Napp.

1865

Mendel began his meteorology studies at the Austrian Meteorological Society.

1868

The genetic discoveries Mendel made were rejected and he became the abbot of the monastery.

1884

Mendel died on 6 January in Brno. His findings were finally given recognition in the 20th century.

© Alamy / Getty

FJORDS

WATERWAYS CARVED BY GLACIERS

How were fjords formed and where can you see them?

WORDS **AILSA HARVEY**

Walled in by steep, rocky cliffs, river-like systems track through some of the planet's most mountainous terrain. The water found flowing here is a combination of freshwater that has run down from the mountaintops and saltwater filling in from the sea. The water traverses mountain valleys like a river, but this is a more unique system known as a fjord.

Relatively rare across the world, fjords are defined by their formation. Their convenient low paths were produced by glaciers as they eroded the land during the last ice age. The movement of glaciers was strongest inland, resulting in the deepest sections of these narrow waterways – sometimes thousands of metres deep – being located farthest from the coast.

Fjords follow a pre-carved path, directing water between dramatic mountain peaks. Throughout history, humans have utilised fjords for inland navigation. The term 'fjord' is derived from this, meaning 'where one fares through' in Norwegian. Norway and other Scandinavian countries hold the highest percentage of Earth's fjords, but this name has been adopted internationally.

Fjords can branch out into many arms, spreading far across the landscape. Many of these stretch into very remote areas, and due to many fjords being difficult to access, they remain largely unpolluted. They also serve as a record of Earth's natural history and a protected environment where the movement of glaciers from many thousands of years ago can be tracked.

Did you know?

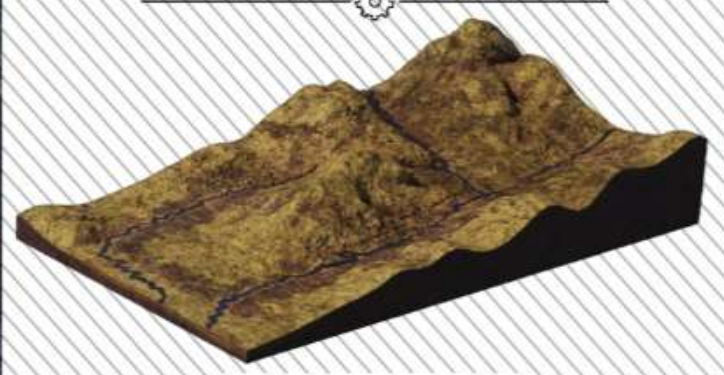
Cold-water coral lives at depths of 40 to 1,000 metres

DID YOU KNOW? Small, rocky islands called skerries can be seen near fjords – these too were carved by glaciers

Harbour seals can rest on the surface ice of frozen fjords

HOW THEY FORMED

Our planet's changing climate shaped the land



1 BEFORE ICE AGE

Around 70 million years ago there was very little ice on Earth. The land surrounding today's fjords was ice-free.

2 ICE AGE

During the Pleistocene epoch, between 2.6 million and 11,700 years ago, the last ice age took place. Large areas of land were covered by glaciers. These form when masses of snow are compacted into giant sheets of ice.

3 10,000 YEARS AGO

As the ice began to melt at the end of the last ice age, the newly exposed land gave ice room to move and spread. When the glaciers moved, the stones they carried with them eroded the bedrock to create valleys.

4 TODAY

Eventually, due to many glaciers melting in a short space of time, sea levels rose. Some of this water flooded the valleys carved by the moving glaciers, producing fjords.

© Getty / Illustration by Nicholas Forder

AR ZONE

FJORD WILDLIFE

What animals thrive both in and around these unique water features?

1 HARBOUR SEAL
These seals can grow up to 1.5 metres in length and congregate on the surrounding rocks during breeding season. Around 10,000 live along Norwegian coasts and venture significant distances up fjords.

2 GREENLAND SHARK
In deep areas of the eastern North Atlantic, these sharks venture inland through fjords. They live in cold waters and so are most likely to be seen in fjords during winter months.

3 KILLER WHALE
Killer whales spend around 40 per cent of their time travelling, giving them enough time to explore fjords. Killer whales use the more enclosed space here to hunt for herring.

4 COLD-WATER CORAL
At the very bottom of fjords, coral reefs contribute to an ecosystem of fish, plankton and sea anemones. A limited number of species can live here due to the extremely high water pressure. Most coral reefs are tropical, living in light, shallow waters, but in fjords, cold-water coral thrives in the darkest depths.

Did you know?
The Vikings used fjords for transport and trade

CANADA
OVER 200 FJORDS
Fjords can be seen on the north, east and west coasts of Canada. The majority are located along the country's north coast.

GREENLAND
OVER 140 FJORDS
The largest fjord in Greenland is also the largest in the world. Scoresby Sund is 217 miles long.

NORWAY
OVER 1,700 FJORDS
Norway is home to a large majority of the world's fjords – it's the country where the term 'fjord' originates from.

CHILE
11 FJORDS
Chilean fjords formed at the southwest coast of South America. They cover an area of 930 miles.

NEW ZEALAND
15 FJORDS
The best known fjord of New Zealand is Milford Sound. This is located at the southwest corner of New Zealand's South Island.

ON THE MAP

Fjords can be found across the globe

© Getty / Illustration by Nicholas Forder

DID YOU KNOW? Many fjords are on UNESCO's World Heritage list because of their 'outstanding universal value to humanity'

5 MOUNTAIN GOAT
The steep surrounding mountains are an environment that suits mountain goats. In Alaskan fjords, these animals of the antelope family occupy the extreme slopes as a form of defence. This habitat puts them out of reach of predators that struggle to navigate these parts.

6 FISH VARIETY
Many fish species thrive in the world's fjords. In Norway, salmon, cod, coalfish and pollack are found in the highest abundance. Around 600,000 Atlantic salmon enter fjords in Norway every year.

7 BLACK OYSTERCATCHER
Fjord birds, such as those inhabiting Kenai Fjords in Alaska, have adapted to be better swimmers than fliers due to the narrow airspace. 191 bird species live here, including the black oystercatcher. These birds hunt for food such as mussels in the sheltered, rocky landscapes.

AR zone
SCAN HERE

A killer whale photographed in Kvænangen Fjord, Norway

FAMOUS FJORDS

GEIRANGERFJORD
This fjord of western Norway, located in Møre og Romsdal county, stretches for nine miles between mountains over 1,000 metres tall. Despite its impressive natural beauty, the fjord and its surrounding mountains – particularly Åkerneset – pose a tsunami threat. As erosion continues, large parts of the unstable mountain may one day crash into the fjord, creating a giant wave.

Geirangerfjord is named after the nearby village of Geiranger

NÆRØYFJORD
This is one of the world's narrowest fjords, with a width of just 250 metres in some areas along its 11-mile length. Its widest point is just 0.62 miles wide. It's one of the branching arms of Norway's longest fjord, Sognefjord, which joins the sea at the coastal city of Bergen.

There are 25 waterfalls feeding into Nærøyfjord

KENAI FJORDS
The Kenai Fjords of Alaska are part of the largest US icefield, called Harding Icefield. This is one of just four remaining in the US. Many fjords make up this icefield, including Aialik Bay, Harris Bay, McCarty Fjord and Nuka Bay. Kenai Fjords National Park contains 40 glaciers, and 60 per cent is made up of snow and ice. As recently as the beginning of the 20th century, some of the icy Kenai Fjords were filled by glaciers.

Holgate Glacier is a large glacier of Aialik Bay fjord

HOWE SOUND
Northwest of Vancouver, Canada, there's a 26-mile fjord known as Howe Sound. Being North America's most southerly fjord, the 285-metre-deep fjord is greatly cherished by locals. Much of the waterway is classified as a fjord, but as the water travels towards the Georgia Strait and opens up, with small islands dispersed within, it becomes a sound. A sound is an inlet of seawater averting from the ocean's main body.

Saint Mark's Summit provides views over Howe Sound

SERPENT SENSES

Discover how these reptiles hear, see and smell

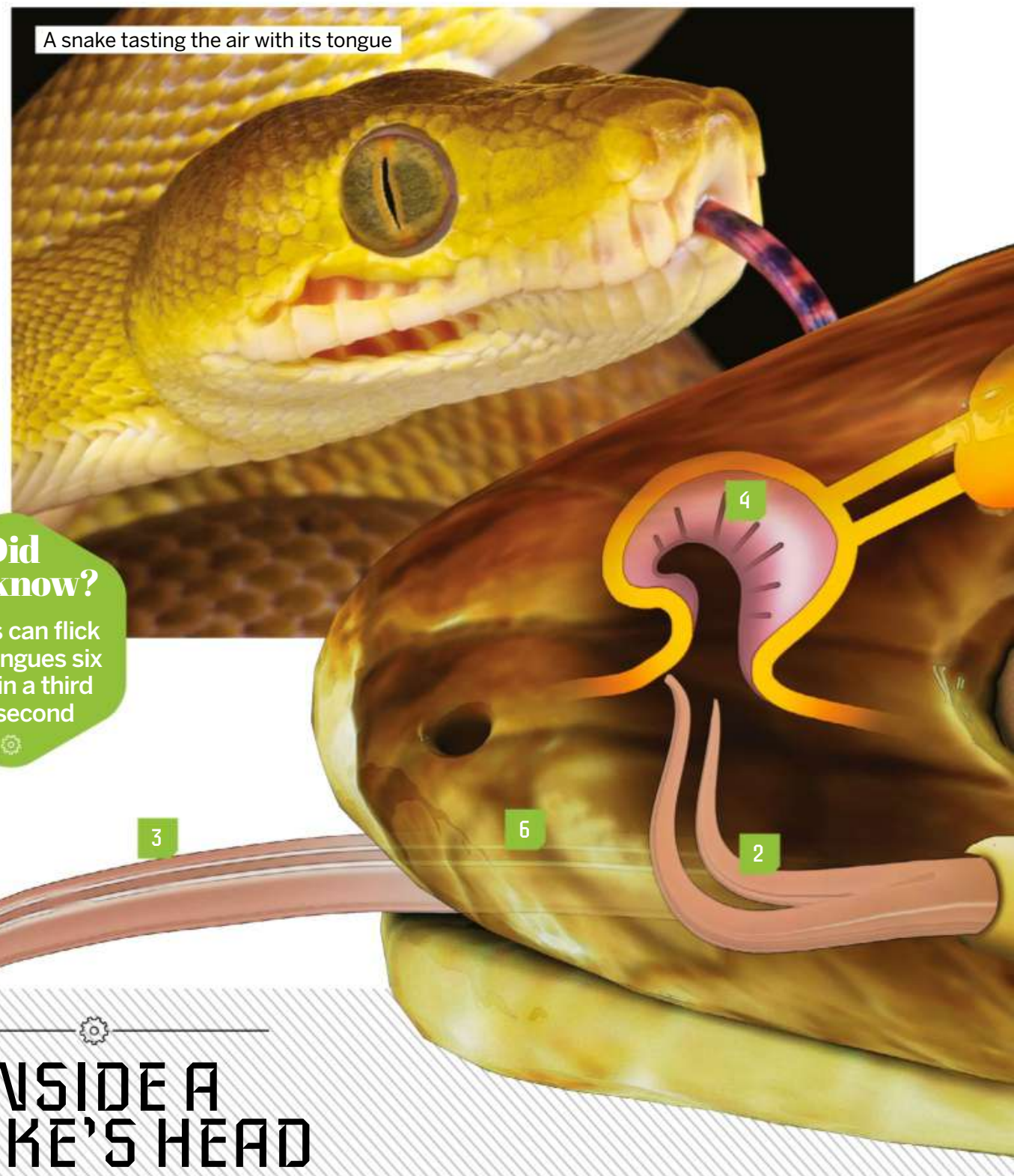
WORDS **SCOTT DUTFIELD**

For around 128.5 million years, snakes have been slithering around sniffing out prey – just not how you might think. Although snakes have nostrils, most of their ability to smell comes from using their tongues. In the same way that odorous particles are hoovered up by human noses, snakes lap up scent particles in the air by flicking their tongues. When the tongue is retracted into its mouth, all the particles that it's collected are delivered to a sensory organ called the Jacobson's organ, also called the vomeronasal organ. The scent particles then bind to receptors in the organ and send that information to the snake's brain for processing and interpretation. Snakes use this keen sense of smell to 'taste' chemical compounds released into the air by prey while they are on the hunt.

Their eyesight isn't so advanced. Like many animals, snake eyes have a diverse range of specialised pigment cells in the retinae that detect light and see colour. These retinal cells allow snakes to have dichromatic vision, meaning they can distinguish between two colours, blue and green, compared to the three that humans see – blue, green and red. Snakes are also visually sensitive to ultraviolet (UV) light. In nocturnal snake species, UV sensitivity has caused them to evolve a UV eye lens that allows this type of light to enter the eye, which also means they can see more clearly in low-light conditions. However, for snakes that hunt in the daytime, their eyes have developed a lens that blocks UV light for visual clarity.

Unlike their keen sense of smell and varying eyesight, a snake's ability to hear is typically minimal. Snakes lack the outer ear and middle ear structures found in keen listeners like humans. However, they have retained a middle ear bone that's connected to their jaw. This is thought to allow them to detect vibrations on the ground but limits their ability to hear sound vibrations that travel through the air.

A snake tasting the air with its tongue



Did you know?

Snakes can flick their tongues six times in a third of a second

INSIDE A SNAKE'S HEAD

What makes snakes such powerful predators?

1 EYELIDS
Snakes share the same eye anatomy as other reptiles, but they don't have any eyelids. Their eyes are protected by a thin membrane called a spectacle.

2 FORKED TONGUE
A snake's tongue is forked so that each tip fits into a hole in the bulb-like vomeronasal organ, where scent receptors are located.

3 TASTE BUDS
Snakes don't have typical taste buds on their tongues like humans, instead drawing in scent particles to their olfactory organ.

4 NO VOICE
Snakes don't use vocalisations to communicate and therefore don't require a keen sense of hearing.

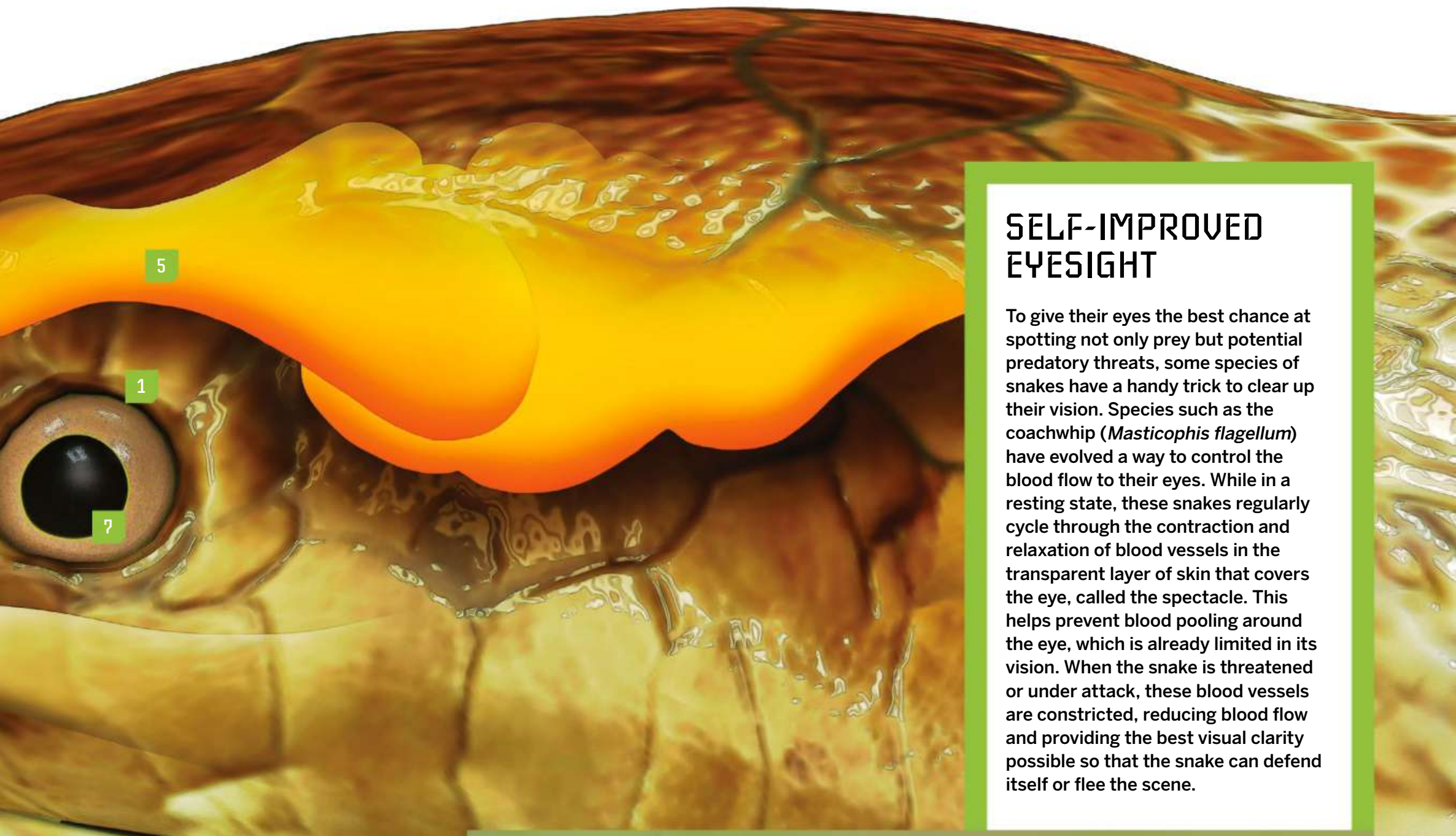
5 EAR
With only a middle ear bone, snakes can detect limited sounds. The middle ear is predominantly used to detect vibrations emanating from the ground.

DID YOU KNOW? Royal pythons can hear sounds at frequencies between 80 and 160 hertz

SEEING IN INFRARED

Eyesight isn't the only way some snakes spot their prey. On the faces of some species, like pythons and pit vipers, are small holes called pit organs. Within each of these is a membrane that can detect the infrared radiation emitted from the warm bodies of passing prey or predators. Each pit organ membrane contains receptors that interpret infrared radiation as heat and feed that information to the snake's brain, allowing them to locate where the heat source is. These pits are extremely sensitive and can detect changes in surrounding temperatures of just 0.001 degrees Celsius. For nocturnal snake species, this gives them a sort of night-vision advantage while on the hunt for warm-blooded prey.

Snakes have a built-in infrared camera for nighttime hunting



SELF-IMPROVED EYESIGHT

To give their eyes the best chance at spotting not only prey but potential predatory threats, some species of snakes have a handy trick to clear up their vision. Species such as the coachwhip (*Masticophis flagellum*) have evolved a way to control the blood flow to their eyes. While in a resting state, these snakes regularly cycle through the contraction and relaxation of blood vessels in the transparent layer of skin that covers the eye, called the spectacle. This helps prevent blood pooling around the eye, which is already limited in its vision. When the snake is threatened or under attack, these blood vessels are constricted, reducing blood flow and providing the best visual clarity possible so that the snake can defend itself or flee the scene.

Coachwhip snakes are able to change blood flow to their eyes for better vision

6 PIT ORGANS
These infrared-detecting organs can spot the heat signatures of other animals from up to a metre away.

7 LENS
Snakes have one of two eye lenses: one that blocks out UV light and another that lets it into the eye for a nighttime visual advantage.

© Alamy / Getty / Science Photo Library

CROCODILES VS ALLIGATORS

The tail makes up about half of an alligator's length

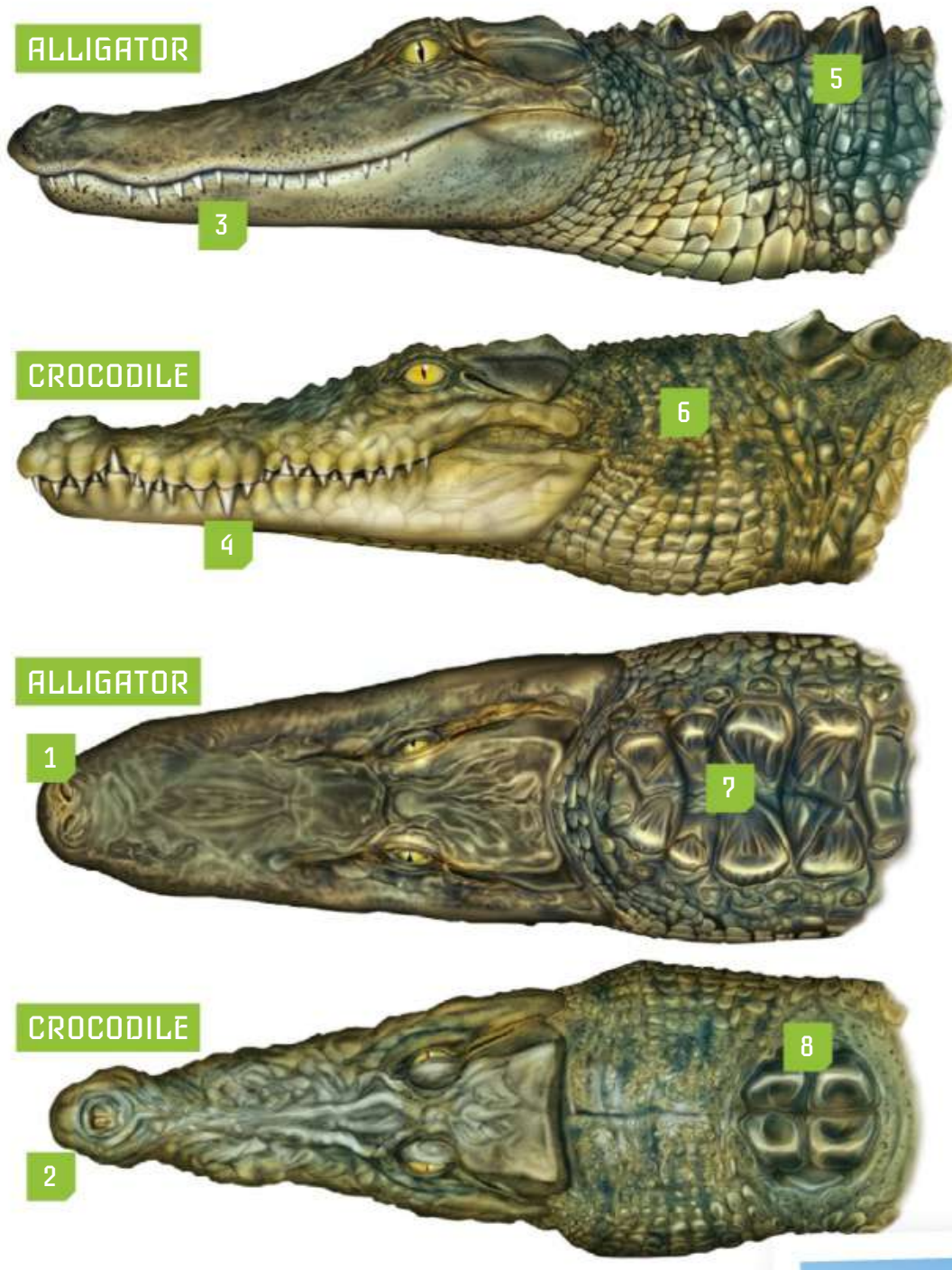
The differences between these cold-blooded creatures are more than skin deep

WORDS **AILSA HARVEY**

If you were to encounter one in the wild, you might find it difficult to determine whether you're looking at a crocodile or an alligator. They spend much of their time submerged below the water, expertly camouflaged and ready to launch their snapping jaws if need be.

Crocodiles and alligators are separate families, but are both members of the order Crocodylia. This means they share very common features and characteristics, from their elongated snouts decorated with dagger-like teeth to their muscular tails used to propel them through the water or as a thrashing defensive weapon.

But if you take a closer look at these animals, you will spot many attributes that set them apart. Firstly, crocodiles are the larger of the two, growing up to six metres in length – almost double that of an alligator. The feet of an alligator are webbed, unlike a crocodile's, helping them swim against the water in their freshwater habitats. Meanwhile, crocodiles have evolved to suit saltwater environments. They can be found in lagoons, rivers, mangrove swamps and on islands.



HEAD TO HEAD

How do their crocodilian features compare?

1 ROUNDED SNOUT
Alligators have wider U-shaped snouts.

2 POINTED SNOUT
Crocodiles have long V-shaped snouts.

3 HIDDEN FANGS
Because of their wider upper jaw, some of an alligator's teeth are hidden when their mouths are shut. They have around 80 teeth.

4 INTERLOCKING TEETH
Crocodiles have 66 teeth. When their mouths are shut you can see the teeth interlocking.

5 DARKER ALLIGATORS
Alligators are usually grey-black. This helps their scales absorb more Sun in cooler climates and remain hidden in murky waters.

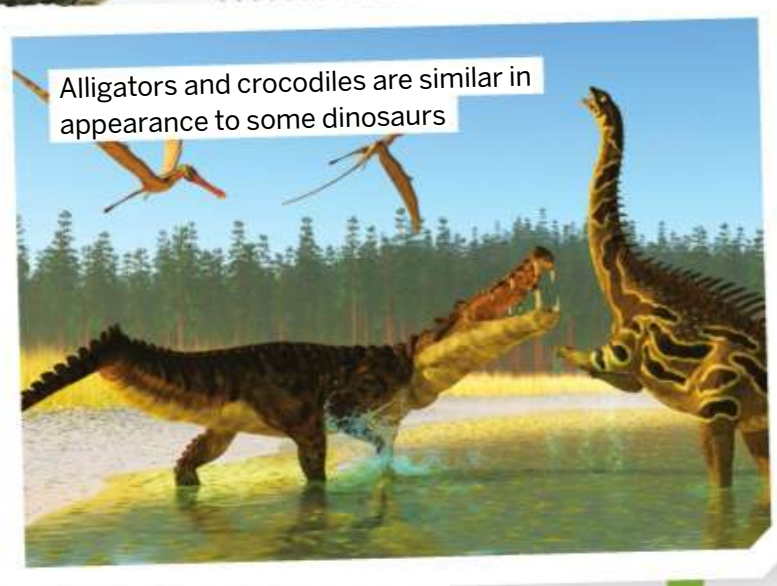
6 CROCODILE COLOUR
The greener complexion of crocodiles better reflects sunlight in warmer environments and makes them more camouflaged in coastal sand.

7 SMOOTH SCALES
Alligators' scales are smaller and smoother than a crocodile's. The arrangement is less uniform, with the smallest scales being towards the sides of the body.

8 SYMMETRICAL SCALES
A crocodile's scales are more regular and rectangular. Like alligators, larger scales are located on the back.

HOW DID THESE REPTILES EVOLVE?

Alligators are truly ancient, with their earliest ancestors appearing around 245 million years ago. Later on, around 80 million years ago, crocodilians evolved. Both of these animals lived on the planet at the same time as dinosaurs, surviving as three-quarters of life on Earth perished in the Cretaceous-Tertiary extinction. It was during the Late Cretaceous period that these reptiles developed their stumpy legs and large, protective scales. In this period, alligators and crocodiles diverged to become two separate families. Despite their slight differences, alligators and crocodiles remain very similar in appearance and haven't had to evolve much over millions of years. This occurs in animals that are biologically adaptable and don't need to change much over time in order to survive. Their Jurassic appearance has led to them being referred to as 'living fossils'.


Alligators and crocodiles are similar in appearance to some dinosaurs

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INSIDE NASA'S FUTURE MOON OUTPOST

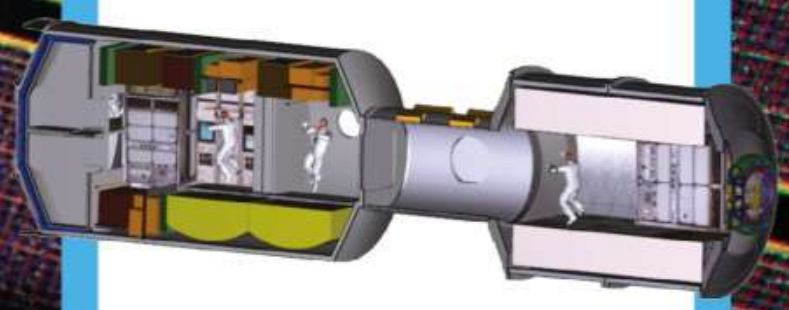
This ambitious new plan will put a space station in orbit around the Moon

WORDS **ANDREW MAY**

DID YOU KNOW? There's a campaign to name the Gateway after Apollo 11's Michael Collins

RETURNING TO THE MOON

NASA's plans for a more ambitious follow-up to Project Apollo go back a long way. In 1992 the agency produced a mission concept called Future Lunar Outpost which would have put a habitat on the Moon's surface capable of supporting astronauts for a 45-day stay. However, NASA chose to focus on an Earth-orbiting space station instead: the ISS. The idea of a similar station in lunar orbit first arose around 2012 in the form of a relatively small deep-space habitat. But it was only with the advent of the Artemis program in 2019 that the full Lunar Gateway concept and its role in supporting a long-duration surface outpost emerged in its present form.



A NASA concept for an ISS-based 'deep-space habitat' from 2012

NASA has grand plans to build a space station in orbit around the Moon. Called the Lunar Gateway, construction could start as early as 2024 and is an essential component of NASA's Artemis program to return astronauts to the Moon. Following the preliminary test flights, the plan is to embark on a series of long-duration missions, and that's where Gateway enters the picture. It will serve as a kind of hotel for astronauts en route to the lunar surface, as well as providing accommodation and workspace for scientists who will spend up to three months at a time carrying out remote observations of the Moon and conducting other scientific studies.

In very simple terms, the Gateway can be seen as a scaled-up version of the Command Module of the Apollo missions, which remained in orbit around the Moon with one astronaut on board while two others descended to the surface. But whereas the Command Module occupied a near-circular orbit around 60 miles above the Moon's surface, Gateway's orbit will be very different. Technically known as a 'near-rectilinear halo orbit', it will take the form of an elongated ellipse around 1,860 miles from the lunar surface at its closest and 43,500 miles at its farthest. That latter figure is almost a fifth of the distance from the Moon all the way back to Earth, which means the dynamics of the orbit will be affected by the Earth's gravity as well as the Moon's. Taking around seven days to complete a revolution, this particular orbit was chosen because it minimises the effort needed to reach it from both Earth and the Moon and maximises the time during which it has direct lines of sight to them.

In many ways, Gateway will be analogous to the International Space Station (ISS), except that it's in lunar orbit rather than Earth orbit. It will be similarly assembled in-situ from a number of separate modules and it will be constructed not just by NASA but by a range of international partners too, including the European, Canadian and Japanese space agencies.

But even when it's completed, Gateway will be a much smaller structure than the ISS, with a total mass of a mere 40 tonnes compared to the 420 tonnes of the ISS. And while there is a continuous human presence on board the ISS, Gateway will only be occupied for around 30 days per year.

Did you know?

24 astronauts have visited the Moon, but only 12 went to the surface

Although the Lunar Gateway will be essential to the success of later Artemis missions, NASA doesn't consider it to be on the 'critical path' to its key objective of returning humans to the surface of the Moon as early as possible, so the ambitious project doesn't have the same intense urgency as other aspects of the Artemis program, such as the Space Launch System (SLS) megarocket and Orion spacecraft. Even so, NASA is busy putting contracts into place that will produce all the necessary Gateway hardware. For example, Northrop Grumman has received a $187 million (£153 million) contract to design Gateway's Habitation and Logistics Outpost (HALO) module. And SpaceX, using its Falcon Heavy launch rocket, has been selected to blast HALO – together with Gateway's solar-power module – into space. NASA's current target is for this launch to take place in November 2024.

© Alamy / NASA

ARTEMIS BASE CAMP

The main role of the Gateway space station is to support human activity on the surface of the Moon. This will include setting up a permanent outpost there, provisionally called Artemis Base Camp. This will be located near the south pole of the Moon – an ideal spot given its likely access to water ice and other useful resources. NASA envisions one crewed visit to the base per year, with the facilities becoming increasingly sophisticated and comfortable over time. The first visits are likely to be relatively brief, but later ones could be as long as two months in duration.

Capable of supporting four astronauts at a time, Artemis Base Camp will eventually have a complete infrastructure for power, communications and waste processing, together with all-important radiation shielding and a dedicated landing pad. It will also have research facilities aimed at testing new technologies for living and working on the Moon, and at least two vehicles to allow the astronauts to explore the lunar surface.

A NASA artist's impression of how Artemis Base Camp might look

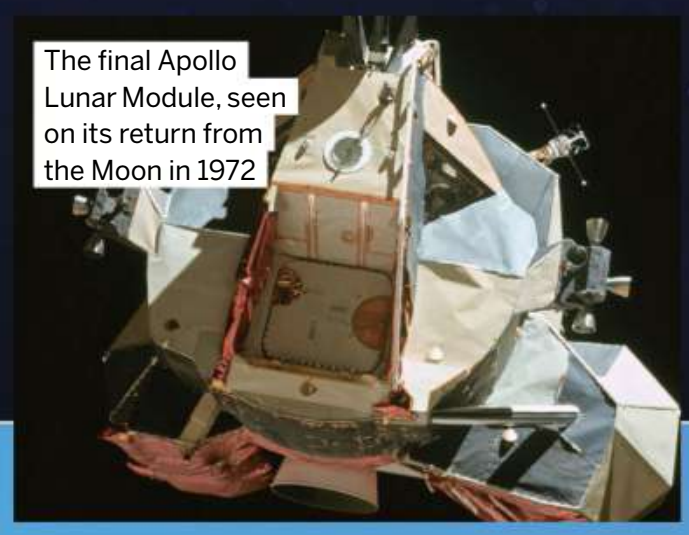
THE LUNAR GATEWAY IN DETAIL

Like the ISS, Gateway will be made up of a number of different modules

ESPRIT
The European System Providing Refuelling, Infrastructure and Telecommunications is being provided by the European Space Agency (ESA).

ORION SPACECRAFT
It's this module that brings astronauts from Earth and returns them home at the end of a mission.

The Artemis astronauts will launch into space atop NASA's new SLS megarocket



The final Apollo Lunar Module, seen on its return from the Moon in 1972

NASA has selected SpaceX's Starship to land Artemis astronauts on the Moon

DID YOU KNOW? NASA chose the name Artemis because she was the sister of Apollo and goddess of the Moon in Greek mythology

LOGISTICS MODULE
Various companies, starting with SpaceX, will provide robotic craft to resupply the station from Earth.
EXTERNAL ROBOTICS
The Canadian Space Agency will provide an external robotic arm, similar to the one on the ISS.
POWER AND PROPULSION ELEMENT
The PPE, built by Maxar Technologies, will be a 60-kilowatt solar-powered module providing electricity, communications and other services.
SPACEX ROCKET
The core elements of HALO and PPE will be launched using SpaceX's Falcon Heavy rocket.
HABITATION AND LOGISTICS OUTPOST
HALO, under development by Northrop Grumman, will provide crew quarters for astronauts en route to the lunar surface.
HUMAN LANDING SYSTEM
The shuttlecraft to take astronauts down to the Moon's surface will be based on SpaceX's Starship vehicle.

NASA'S FUTURE VISION FOR GATEWAY

We speak with Gateway program manager Dan Hartman about his hopes for the project

Why was this orbit chosen?
Gateway will travel around the Moon in a near-rectilinear halo orbit (NRHO). It will be balanced between the Earth's and Moon's gravity, which makes the orbit very fuel efficient and cost-effective. NRHO is about a one-week orbit that will periodically bring Gateway close enough to the lunar surface to provide access to a variety of locations, such as the Moon's south pole. NRHO will also give Gateway a continuous line of sight to Earth, unlike other orbits where you lose signal when vehicles travel around the far side of the Moon. A challenge with NRHO is that it's new for NASA and its international partners, so we are learning as much as we possibly can before we launch.

Did you know?
A spacecraft takes about three days to reach the Moon

What science activities can the station do in between visits by human crews?
We are building Gateway with research and science in mind. Services and accommodations for payloads are part of the initial design, providing unique options for Earth science, heliophysics, lunar and planetary sciences, life sciences, astrophysics and fundamental physics investigations by allowing views of the Earth, Sun, Moon and space not possible from Earth's surface or from Earth orbit. We will get to study potential impacts of space weather on people, instruments and equipment in ways not possible closer to Earth.

What's the long-term plan for Gateway beyond the initial Artemis program?
We think that Gateway is going to be a huge part of what gets us to Mars. Given how Gateway is built and where it will operate, it will have the capabilities to help send humans beyond the Moon. We think it's likely that Gateway will play a very real role – it will be a very real gateway to Mars.

© Alamy / NASA / SpaceX

WHAT IS RED LIGHTNING?

These red flashes can sometimes be seen shooting upwards into the top of the atmosphere. Here's why they happen

WORDS **ANDREW MAY**

Red lightning, also known as a 'sprite', is an intriguing weather phenomenon associated with very intense thunderstorms. While an ordinary lightning flash extends down from the clouds to the ground, a sprite shoots way up into the upper reaches of the atmosphere. But it only lasts for a millisecond or so, making it difficult to observe and study.

Given their elusive nature, 'sprite' is an appropriate name, although it actually stands for Stratospheric Perturbations Resulting from Intense Thunderstorm Electrification. Like regular lightning, it's caused by a buildup of electrical charge in clouds, but in this case the excess charge is released into the ionosphere – around 50 miles up – rather than to the ground. Sprites are usually red in colour and can range in shape between a jellyfish and a carrot. Compared to an ordinary flash of lightning they can be huge in size, often as much as 30 miles across.

Although it looks striking when captured in a photograph, red lightning isn't easy to observe from the ground for the obvious reason that it occurs far above the cloud layer. It can be seen more clearly from high-flying planes – including specially instrumented research aircraft – and it's also been observed by astronauts on the International Space Station (ISS).

Red lightning isn't the only upper-atmosphere phenomenon that can be triggered by thunderstorms. Collectively known as transient luminous events, or TLEs, other examples include blue jets, which are optical ejections from the core region of a thunderstorm, and 'elves' – Emission of Light and Very low-frequency perturbations due to Electromagnetic pulse Sources – which are rapidly expanding disc-shaped regions of luminosity.

> "They range in shape between a jellyfish and a carrot"

A photograph taken from the ISS showing a red sprite clearly visible on the right

Did you know?

Sprites may account for some UFO reports

5 FACTS ABOUT LIGHTNING

1 THE EDGE OF SPACE
The sprites observed by astronauts on the International Space Station in 2015 were seen to extend at least 62 miles above Earth's surface.

2 GIANT ELVES
Although they last less than a thousandth of a second, the disc-shaped glow of elves can expand to as much as 300 miles across.

3 NOT SO HOT
Red lightning doesn't reach the extremely high temperatures of ordinary lightning, being more akin to the glow of a fluorescent tube.

4 DANGEROUS SPRITES
A sprite has caused a high-altitude mishap on at least one occasion, when it led to a NASA stratospheric balloon losing its payload in 1989.

5 THE SPOOKY STRATOSPHERE
As well as sprites and elves, other lightning-related phenomena in the upper atmosphere have been named trolls, pixies, ghosts and gnomes.

SPRITES IN SPACE

In common with many weather phenomena, red lightning could in principle occur on other planets that have an atmosphere, not just Earth. It's been known, for example, that ordinary lightning is a common occurrence in Jupiter's atmosphere ever since NASA's Voyager 1 probe flew past the giant planet in 1979. In the case of sprites specifically, researchers at Tel Aviv University carried out an experiment in 2011 to test whether they could occur on Jupiter, its neighbouring gas giant Saturn and our own near neighbour Venus. They recreated the atmospheres of these planets in their laboratory and passed electrical discharges through them. They found that under the right conditions, sprites could form on all three planets. In the case of Jupiter, the theory was finally confirmed in 2020 when observations from NASA's Juno spacecraft showed that both sprites and elves do indeed occur in the planet's upper atmosphere.

A NASA illustration showing what a sprite might look like in Jupiter's atmosphere

DID YOU KNOW? As well as red lightning, some thunderstorms shoot gamma rays and antimatter into space

UPPER ATMOSPHERIC PHENOMENA

Sprites and elves occur at much higher altitudes than most weather phenomena

ELVES
A brief, high-altitude flash similar to a sprite, but taking the form of a vast, expanding disc.

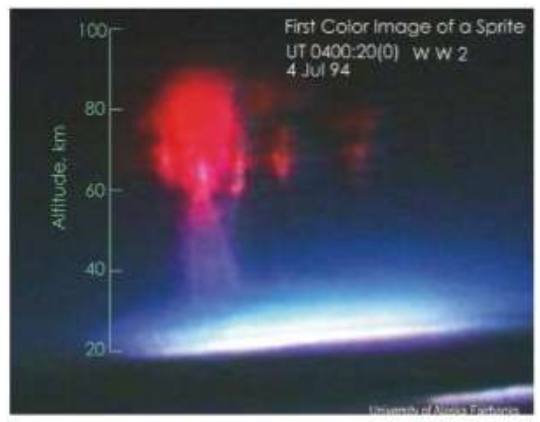
BLUE JET
These bright-blue flashes are similar to lightning, but extend upwards from the clouds instead of down.

SPRITE
Red in colour and very short-lived, these are formed very high up in the atmosphere.

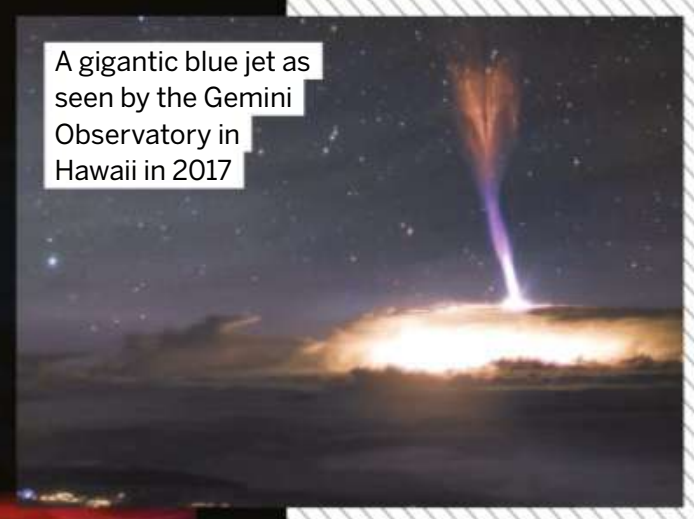
LIGHTNING
The electrical storms we're familiar with occur in the lower atmosphere, below the clouds.

SEEING SPRITES

Anecdotal accounts of lightning-like phenomena occurring above thunderstorms go back to the 19th century, but it was only in the 1950s – when red lightning was observed from airliners and tentative physical theories were described – that it entered the scientific domain. The first photograph of a sprite was taken by accident in 1989 when a team from the University of Minnesota recorded an upward flash from the cloud tops while they were testing a low-light TV camera. Over the next few years, video recordings made by astronauts on the Space Shuttle captured several more examples, placing the phenomenon on a much firmer observational footing.



The first colour image of a sprite, taken from a research aircraft in 1994



A gigantic blue jet as seen by the Gemini Observatory in Hawaii in 2017

Jupiter is the only other planet where sprites have been observed

© Science Photo Library / NASA / National Optical-Infrared Astronomy Research Laboratory

INTO THE MILKY WAY'S MASSIVE BLACK HOLE

At the heart of our galaxy lies the supermassive black hole Sagittarius A*. Here's what we know about this cosmic titan

WORDS **ROBERT LEA**

At the centres of most large galaxies dwell titanic space-time events known as supermassive black holes, with masses in excess of millions or even billions of times that of our Sun. Our spiral galaxy, the Milky Way, is no different, hosting a massive, compact object in its central region known as Sagittarius A* (Sgr A*). Though our supermassive black hole is mostly dormant, only occasionally swallowing gas or dust, it's no less fascinating than that of any other galaxy. Though many mysteries surround Sgr A*, astronomers aren't completely in the dark about it, learning a great deal about the sleeping giant at the heart of our galaxy. Everything in our 13.6-billion-year-old galaxy orbits Sgr A*, including our Solar System, located 26,000 light years away, which travels through space at speeds of around 515,000 miles per hour, yet still takes approximately 250 million years to complete a single trip around the galactic centre.

Stellar-mass black holes and intermediate-mass black holes form when massive stars cease nuclear fusion and can no longer support themselves against complete gravitational collapse, but the mechanism that forms supermassive black holes like Sgr A* isn't clear, as there are no stars large enough to directly collapse into a black hole of this size. Two possible mechanisms include smaller black holes growing to tremendous sizes by swallowing gas and dust from their surroundings or by the hierarchical mergers of smaller black holes.

Theories surrounding the Milky Way and its massive occupant date back to the early 1930s, when Karl Jansky found a radio signal emitting from a location in the direction of the constellation of Sagittarius, directed towards the centre of the Milky Way. The galactic centre compact radio source Sgr A* was then identified in February 1974 by astronomers Bruce Balick and Robert L. Brown. It was during the 1980s that astronomers formulated the idea that the central compact object was likely to be a black hole of a size until then unimaginable. In 1994, German astronomer Reinhard Genzel and a team from Berkeley would use infrared and submillimetre spectroscopy to infer a compact object with a mass 3 million times that of the Sun in the region. Over the following decade, astronomers would continue to rule out other possible candidates for this object, including tightly clustered stars, thus strengthening the idea it was supermassive black hole.

Conclusive evidence that the compact object Sgr A* is a supermassive black hole was delivered in 2018 when emissions caused by magnetic interactions from hot gas clumps close to the black hole moving at around 30 per cent the speed of light were observed by astronomers using the GRAVITY interferometer and the Very Large Telescope (VLT) in Chile. These observations exactly matched theoretical predictions for hotspots orbiting close to a black hole with a mass of 4 million solar masses. Astronomers have also learned some other important details about this titanic object, such as its tremendous mass and size – quite the feat considering that Sgr A* can't be 'seen'.

Black holes are notoriously difficult to spot and observe, usually only inferred by the effects they have on their environments. Not only do they not emit light, but black holes also trap photons behind a boundary called the event horizon, making their direct study in optical light near impossible. Observing Sgr A* from Earth is made even more difficult due to the fact that it's shrouded by a thick screen of intervening dust lying between it and us. Fortunately, astronomers have

Did you know?

The * in Sgr A*, added in 1982 by Brown, means 'exciting'

DID YOU KNOW? In 2018 astronomers found that Sgr A* is surrounded by thousands of smaller stellar-mass black holes

An illustration of a supermassive black hole similar to Sgr A*

developed other ways of gaining insights into Sgr A*. For instance, the mass of a central body and its radius can be determined by observing the gravitational influence that it has on the objects that orbit it.

Doing this for Sgr A* has involved monitoring the star S2, with its highly elliptical 16-year orbit, for many years. In 2008, using the star – which orbits Sgr A* at a speed of 17.1 million miles per hour, or around 2.6 per cent the speed of light at a distance of 11 billion miles – and others close to Sgr A*, Genzel and American astronomer Andrea Ghez found it to have a mass 4.3 million times that of the Sun. This discovery would scoop the duo the 2020 Nobel Prize in Physics. Astronomers have also determined a diameter for the Milky Way's supermassive black hole of around 14.6 million miles – the size of a ring of 168 Jupiters. That's still tiny compared to the 100,000-light-years-wide, 1,000-light-years-thick Milky Way.

Also dwarfing Sgr A* is a disc of gas surrounding it that extends for between 5 and 30 light years, occasionally feeding matter to Sgr A* and causing faint flashes of X-rays. This accretion disc is also connected with X-ray emissions caused by friction driving temperatures in the disc up to 10 million degrees Celsius. There is still a great deal to learn about Sgr A*, but the first image of the Milky Way's central black hole, recently taken by the Event Horizon Telescope (EHT), could reveal further secrets held by the cosmic object that has shaped our galaxy.

> "Though many mysteries surround Sgr A*, astronomers aren't completely in the dark"

Sgr A* has now been imaged, confirming its place at the heart of the Milky Way

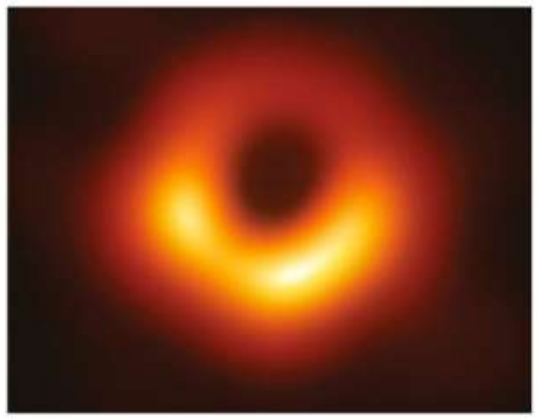
WILL WE BE EATEN?

Despite the common belief, black holes don't actually suck in material, instead just capturing matter that ventures too close to them. Black holes pick up gas and dust in their vicinity, surrounding them in an accretion disc that gradually 'feeds' matter in. When this happens, the violent conditions in the accretion disc create powerful emissions and jets from an area that's called an active galactic nucleus (AGN). Sgr A* isn't currently swallowing enough matter to power an AGN, and a star or other object would have to hit it almost directly to be consumed.

Artist's impression of an active galactic nucleus powered by a black hole

DIRECTLY IMAGED

Despite being the closest supermassive black hole to Earth, Sgr A* wasn't the first to be directly imaged by astronomers. That honour went to the black hole at the heart of galaxy Messier 87, captured by the Event Horizon Telescope (EHT) in 2019. Located 53.5 million light years away, Messier 87's central black hole is a true monster in comparison to Sgr A*, possessing a mass that is around 6.5 billion times the mass of the Sun. A more detailed image of the same black hole followed in 2021, showing the polarisation of magnetic fields around the monster at the heart of Messier 87.



Messier 87's supermassive black hole was the first imaged with the EHT

© Getty / EHT / NASA

TECHNOLOGY

HOW LASERS ARE RESHAPING MODERN WARFARE

WORDS **MARK SMITH**

Whether it's navy ships or armoured vehicles, militaries all around the globe are taking lasers from the pages of fiction and turning them into the weapons of today

DID YOU KNOW? High-energy laser systems have a heating effect, so can take several seconds to work

A laser weapon on the USS Dewey

Did you know?

Some lasers are so bright they can be seen up to 0.6 miles away

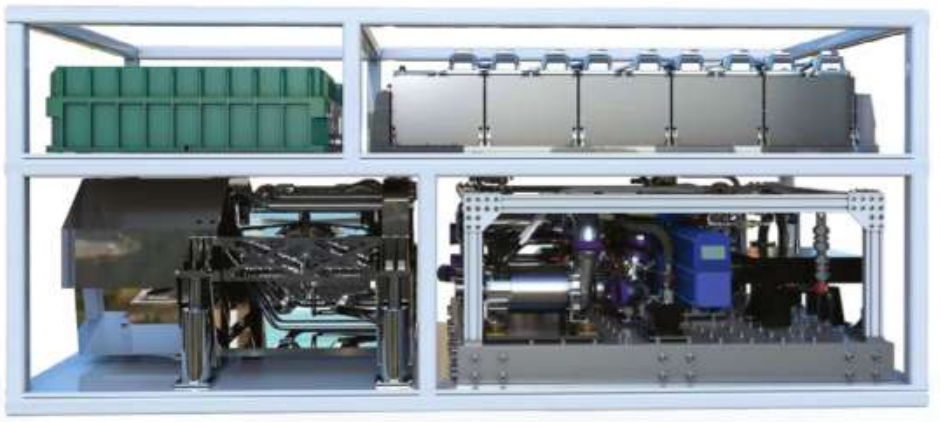
The USS Ponce is equipped with laser weapon systems

From James Bond to *Star Wars*, lasers have always been some of the coolest bits of technology found in the most fantastical stories. Whether it was the Death Star pulverising Alderaan or Goldfinger trying to get Sean Connery to talk, they've always seemed like a science fiction device found purely in the imagination of writers, directors and special-effects gurus. But lasers are a real-world technology that's already used widely in electronics and things like hair removal and cataract operations. The time is fast approaching, too, where they'll be used on the battlefield just as much as bombs, missiles and bullets.

The fascination with laser weapons, made famous by books such as H. G. Wells' *The War of the Worlds*, saw the British Ministry of Defence in the 1930s offer a cash prize for anyone who could invent a 'death ray' that could destroy a sheep at 100 yards. While that work never came to fruition, the research was taken in a different direction and sowed the seeds for what would eventually become radar.

Lasers entered industrial use in the 1960s, but putting them to military use still proved to be tough. President Ronald Reagan envisaged an orbital platform of laser-firing satellites that could wipe out incoming nuclear missiles. Nicknamed the Star Wars program, the tech was never up to the job, and the program was scrapped in the 1990s. But the research continued.

Thanks to the advent of fibre laser technology, systems shrunk to a level where they could be


General Atomics Electromagnetic Systems (GA-EMS) can target unmanned vehicles, missiles, rockets, artillery and mortars

A French military vehicle used a laser to destroy a small drone, the first such success in Europe

HOW HIGH-POWER LASERS WORK

At its most basic level, a laser is a supercharged beam of light particles called photons. The key to getting these particles to do what you want is by 'exciting' the photons, which means giving them lots of energy so that they gain enough power to be aimed and fired at a target.

Laser itself stands for 'light amplification by stimulated emission of radiation' and consists of four basic parts. The first is a source of atoms in what is called a 'lasing medium' – it can be a gas, solid or liquid. The second is an energy source, which is needed to get the atoms 'excited'. The third is mirrors, usually a full mirror and a half-silvered mirror. These are used to allow the emitted light to bounce back and forth in the lasing medium while they build up energy. The fourth component is a lens, which focuses the beam of now-excited photons and allows it to be aimed at a target.

The LaWS weapons system mounted on a US Navy vessel

© Alamy / Getty / Generalatomics / US Navy

fitted on vehicles, aircraft and ships. This leap forward resulted in a number of breakthrough tests, such as in 2016 when Lockheed Martin's 30-kilowatt Advanced Test High Energy Asset (ATHENA) was used to disable a vehicle's engine from more than a mile away.

While their use as a weapon has always seemed a long way off, lasers have been used for other military purposes with great success. Weapon system guidance – where a laser is reflected from a target so a missile or bomb can more accurately home in – is one such use. But developing a solid-state laser weapon has remained difficult. Not only do they not need to be replenished with ammunition, in theory they would also have huge destructive power. Because of the size and huge power requirements of lasers, it has been naval vessels that have had the bulk of the early trials. The US Navy deployed the first high-energy laser weapon system, known as LaWS, on the USS Ponce in 2014, with a reported 30-kilowatt output.

Ground and air forces have also been developing laser weapons. The US Army has been working on the High Energy Laser Tactical Vehicle Demonstrator (HEL TVD), a truck-mounted 100-kilowatt-plus laser weapon that is designed to defend infrastructure such as airfields. In 2020, the US Air Force deployed the service's first high-energy laser – Raytheon's High Energy Laser Weapon System (HELWS) – for battlefield use against drones. This year the US Army plans to deploy 50-kilowatt lasers mounted to Stryker armoured vehicles. These are designed to defend against drones, artillery and rockets. The US government has also awarded a team a contract to build a prototype 300-kilowatt laser weapon, with a demonstration planned for later this year.

Despite these advances, the expense of developing the technology and the huge power requirements for generating an effective laser mean the days of a soldier being able to fit a laser pistol into his holster are still some way off. Until then, we'll have to stick to games of laser tag.

Did you know?

High-energy military lasers are invisible, unlike those in films

Laser blasters have been made famous by the likes of Han Solo in *Star Wars*

"Not only do they not need to be replenished with ammunition, they would also have huge destructive power"

Boeing's HEL MD can take down multiple targets

LASER ON WHEELS

One example of battlefield laser technology that the industry has high hopes for is the High Energy Laser Mobile Demonstrator (HEL MD). Essentially a giant truck with a laser on its back, it has been in development since 2011. In 2013 it shot down several unmanned aerial vehicles (UAVs) in flight as well as more than 90 mortar rounds at the High Energy Laser Systems Test Facility located at White Sands Missile Range, New Mexico. It fired a ten-kilowatt laser in that test, but future plans include tests with a 50 and then 100-kilowatt laser – this means it could engage cruise missiles, rockets and even artillery.

CHINA'S NEW LASER RIFLE

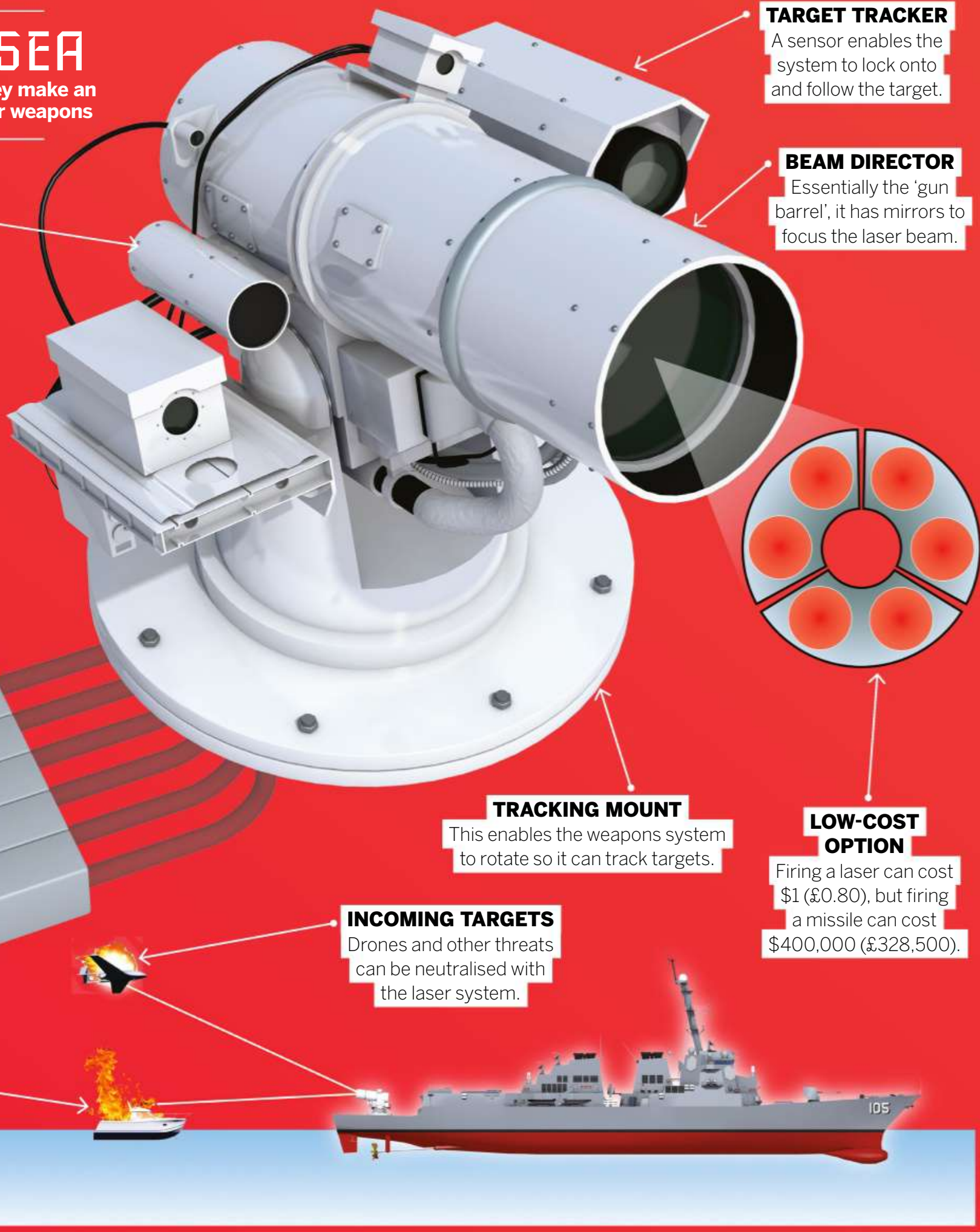
Mystery surrounds one piece of intriguing technology purported to be a Chinese 'laser rifle'. In 2018 the Communist country's military claimed to have created a revolutionary new type of laser rifle straight from the movies. Branded the ZKZM-500, it's supposedly capable of burning a hole in an enemy soldier from half a mile away.

Manufactured by ZKZM Laser, it supposedly weighs around 2.7 kilograms and was claimed to have a range of 800 metres. China said the rifle consists of two important components, the laser and its lithium battery, which account for most of its weight. But many industry experts in the West were heavily sceptical of the claims.

DID YOU KNOW? Lasers started life in the 1960s and were initially used to drill for diamonds

LASERS AT SEA

The size of warships means they make an ideal platform for modern laser weapons



TARGET TRACKER
A sensor enables the system to lock onto and follow the target.

BEAM DIRECTOR
Essentially the 'gun barrel', it has mirrors to focus the laser beam.

RADIO FREQUENCY SENSOR
This provides the operator with the range to the target.

BELOW DECK
The bulk of the tech that powers the system is housed below deck on the ship.

TRACKING MOUNT
This enables the weapons system to rotate so it can track targets.

LOW-COST OPTION
Firing a laser can cost $1 (£0.80), but firing a missile can cost $400,000 (£328,500).

INCOMING TARGETS
Drones and other threats can be neutralised with the laser system.

SURFACE TARGETS
Even if a boat is fast, it can't outrun the laser beam.

AR zone

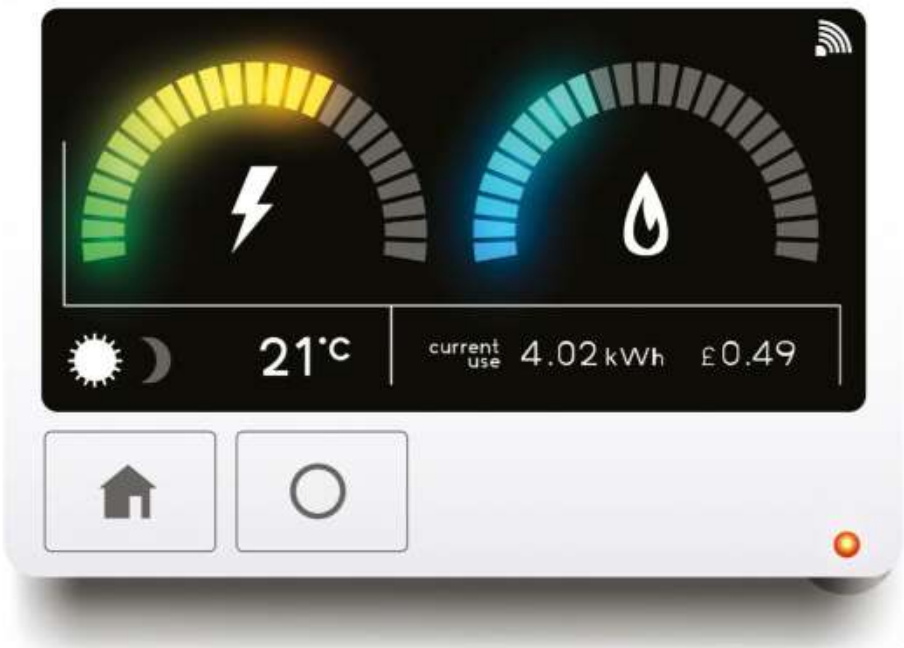
SCAN HERE

A USS Ponce weapons test in 2014

Operators control the laser weapons

A Northrop Grumman laser weapon ready for transport

© Boeing / Alamy / Illustrations by Adrian Mann

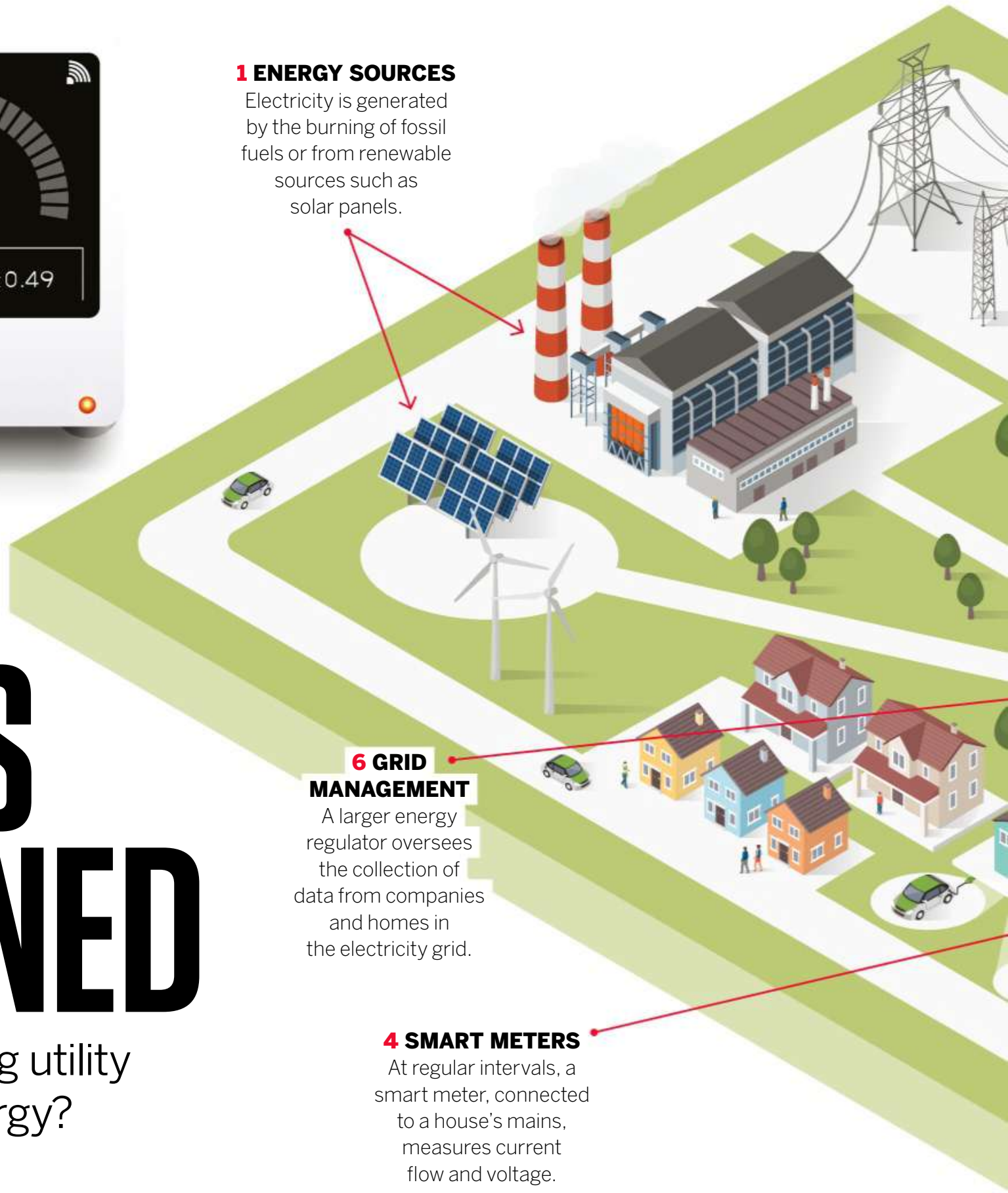


SMART METERS EXPLAINED

How do these self-reading utility meters work to save energy?

WORDS **AILSA HARVEY**

If you're looking to gain more control over your utility bills, smart meters are the latest devices that give you easy access to all of your energy usage data. Built with a display screen, the meter can be plugged into the mains of your home and presents real-time information about gas and electricity usage, as well as the accumulated cost for the end of that month. Not only does a smart meter provide you with information, it also sends the data to your energy supplier and power generation plants automatically. This improves the process of energy generation as it provides helpful information about energy demands and trends. Those operating smart grids use data from smart meters to predict peak demand times. During these times, electricity generation is accelerated. This method allows energy generation to be lowered slightly at other times, for a more environmentally friendly system.


1 ENERGY SOURCES
Electricity is generated by the burning of fossil fuels or from renewable sources such as solar panels.
6 GRID MANAGEMENT
A larger energy regulator oversees the collection of data from companies and homes in the electricity grid.
4 SMART METERS
At regular intervals, a smart meter, connected to a house's mains, measures current flow and voltage.

ELECTRICITY SMART METER TYPES

Not all smart meters have the same capabilities. The two main types are called SMETS1 and SMETS2, an abbreviation for Smart Metering Equipment Technical Specifications. The former use 3G to connect to electricity suppliers, so when you switch to a new supplier they will lose their 'smart' powers and work like a standard analogue meter – this is often referred to as 'going dumb'. Despite this setback, SMETS1 meters remain the most common. Many people in the UK are now choosing SMETS2 meters instead, however. Each meter of this type sends the data received to one central data network. This means switching suppliers won't make it 'go dumb' and you can still access your meter's data.

All smart meters installed by Bulb Energy are SMETS2 meters

DID YOU KNOW? 50,000 analogue meters are being replaced by smart ones on the Isle of Man as part of a four-year project

THE SMART GRID

How a smart meter fits into the electricity network

2 TRANSMISSION SUBSTATION
Before electricity reaches your home, substations reduce the voltage to make transmission safer.

3 ELECTRICITY DISTRIBUTION
When the voltage has been lowered, it's delivered to a distribution network for homes and businesses.

5 ELECTRICITY COMPANIES
Via a secure wireless network, a smart meter automatically sends electricity use data to the appropriate supplier.

Did you know?
There are more than 25 million smart meters in Britain

5 BENEFITS OF USING A SMART METER

1 BILL ACCURACY
Because energy usage information is constantly being measured, you won't be charged based on estimated values.

2 AN EYE ON THE COST
The monthly cost of your electricity can be displayed on the smart meter screen as it is being used.

3 REDUCED CONSUMPTION
A smart meter makes you more aware of when you are using a lot of electricity. In most cases, this helps people actively reduce energy consumption.

4 LOWER CARBON FOOTPRINT
If everyone in Britain switched to a smart meter, the carbon dioxide savings made would be equal to 70 million trees.

5 ACCESSIBLE DATA
Some smart meters can divide bills into prices per individual electrical item. This data can be viewed on a mobile phone.

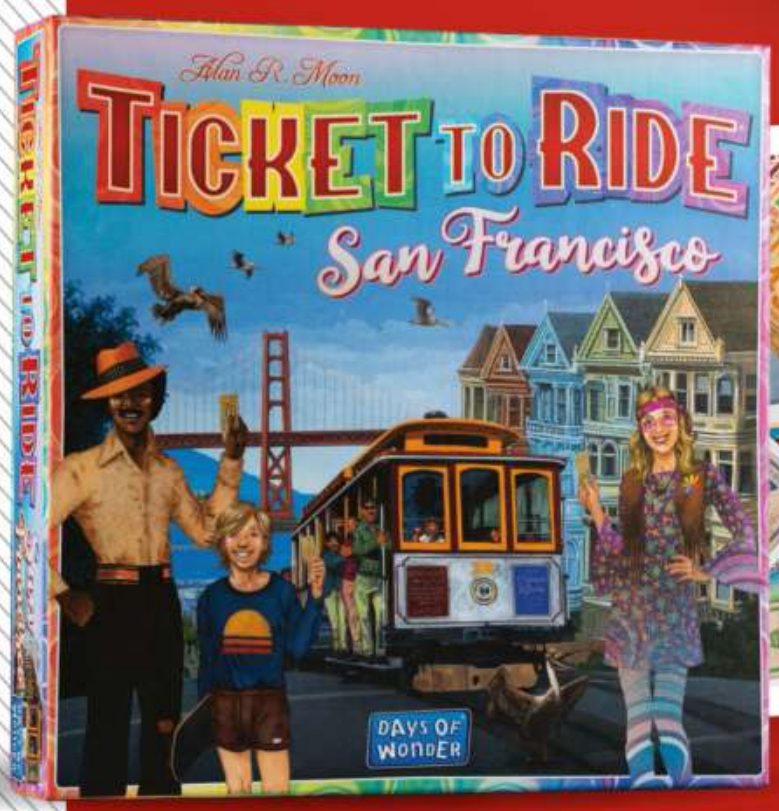
A smart meter comes in two main parts: this part is connected to the electricity mains while an in-home display is more end-user friendly

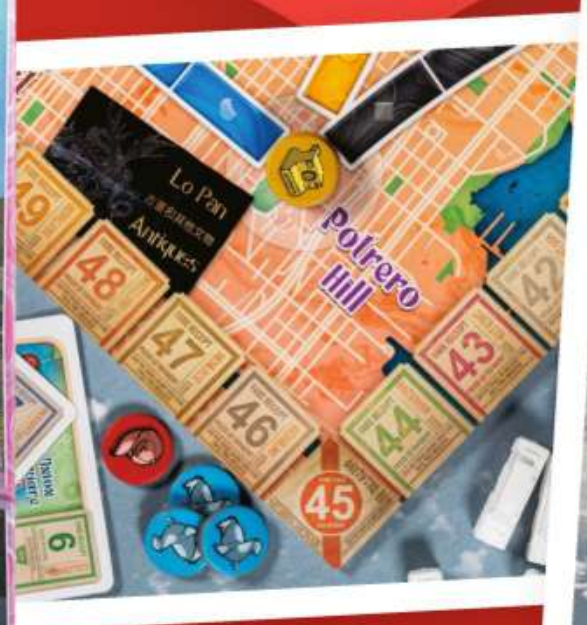
© Alamy / Getty

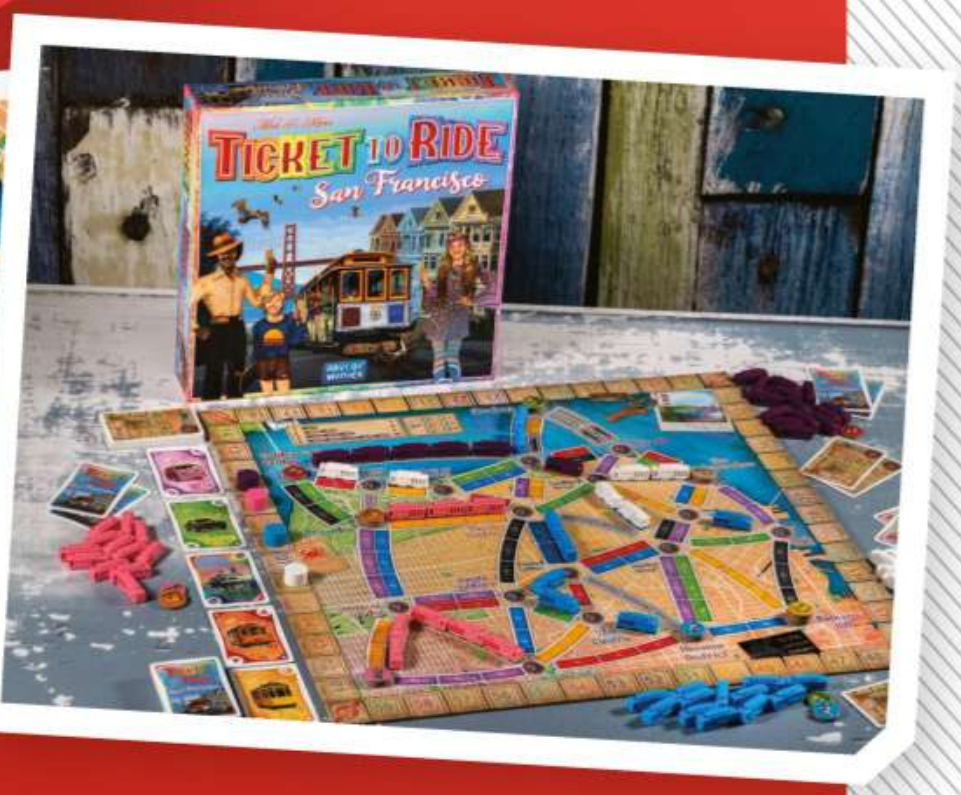
Win!

ONE OF FIVE COPIES OF TICKET TO RIDE: SAN FRANCISCO

Ticket to Ride is heading to San Francisco, and we're giving you the chance to win one of five copies of the board game, courtesy of Asmodee. The latest edition features familiar gameplay from the *Ticket to Ride* game series – collect cards, claim routes and draw tickets – but on a map of 1960s San Francisco. Among locations on the board are Alcatraz, the Golden Gate Bridge and the Painted Ladies, the city's iconic row of vivid houses by Alamo Square







For your chance to win, answer the following question:

Where in the United States does the Statue of Liberty stand?

A: GALVESTON BAY B: THE LOS ANGELES RIVER C: NEW YORK HARBOUR

Enter online at **howitworksdaily.com** and one lucky entrant will win!

Terms and Conditions: Competition closes at 00:00 BST on 28 July 2022. By taking part in this competition you agree to be bound by these terms and conditions and the Competition Rules: **www.futuretcs.com**. Entries must be received by 00:00 BST on 28/07/2022. Open to all UK residents aged 18 years or over. The winner will be drawn at random from all valid entries received and shall be notified by email or telephone. The prize is non-transferable and non-refundable. There is no cash alternative.

©Asmodee Games

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OFFER EXPIRES 31 AUG 2022

Solar coronas are yet to be fully explained

Did you know?
The corona is the ring around the Sun during a total eclipse

What is the solar corona?

Neil Harmon

The solar corona is a part of the Sun that spreads out from our star's surface. The word means 'crown', which is quite appropriate for the monarch of the Solar System. Because the corona is not very dense, it's hard to observe. During a solar eclipse, however, the Moon blocks the glaring light from the Sun and we can see the corona in its full glory. Observatories in space keep a constant eye on this crown and send us images of its always-changing features, modelled by magnetic fields and the solar wind, which is made up of charged particles emitted by our star. At over 2 million degrees Celsius, the corona is strangely much hotter than the surface of the Sun below. Astronomers are still looking for a precise explanation for this, but it appears that magnetic fields are responsible for making the corona so hot.

Palm oil farming has destroyed many habitats

WHAT IS THE ENVIRONMENTAL IMPACT OF USING PALM OIL?

Diane Brown

Palm oil is used in many food and cosmetic products and has been championed as a source of green, sustainable fuel. It's a huge part of the export revenue for countries such as Indonesia and Malaysia. However, there's significant concern worldwide about its sustainable credentials.

The massive expansion of oil palm over tropical forest and bogland has had significant impacts both on large species such as orangutans as well as countless other species of tropical plants, invertebrates, birds, mammals and reptiles by destroying large tracts of natural habitat. The growth of the plantation economy also impacts heavily on local communities, which traditionally relied on forest resources and who do not necessarily benefit from industrial government-driven schemes.

Did you know?
Palm oil is semi-solid at room temperature

Moreover, its credential as a 'green' fuel is very questionable, and many researchers believe that the standing forests the plantations replace are important carbon sinks. So overall – given the high production, processing and transport costs of the oil – retaining the forest and continuing to use fossil fuels might be more effective in reducing carbon emissions, at least in the short term.

HOW DOES DETANGLING SHAMPOO WORK?

Lisa Frampton

Hair is made up of the root and the shaft. The shaft, which is what we see on top of our heads, is biologically dead and made up of three parts: the medulla, the cortex and the cuticle. The cortex is made up of keratin proteins, which have a high percentage of negatively charged amino acids. The cuticle consists of several flat cells laid out like roof tiles. As the shaft is damaged, these cells become loose or fall off, leaving the cortex exposed. These rough cells get caught and tangle up.

Detangling shampoo contains negatively charged ingredients which remove dirt, natural oils and positive charges from the hair. It also contains positively charged ingredients which are attracted to the amino acids on the cortex. These ingredients also repel water, so are not washed out easily, leaving your hair coated with a thin film. This film closes the gaps left by damaged cuticle cells, making it easier to comb and detangle.

WHY DO THE FUSES SOMETIMES BLOW IN MY HOUSE?

Timothy Ball

When a certain amount of current being drawn from a plug socket is exceeded, the fuse is designed to 'blow' to protect the wiring in the house and the appliances connected to that specific circuit. Electricians install fuses as a safety feature so that a large surge in power doesn't cause an electrical fire. A fuse is simply a small wire running from one electrode to another, encapsulated in some kind of fireproof casing. An appliance that needs more power than a fuse can supply will ultimately blow the fuse. Most houses use circuit breakers that operate by similar means, though these differ from fuses in that they can be reset. If too many appliances try to draw power from a wiring system at once, switching on a new one can 'trip' the breaker and cut power, which is why switching on an appliance can cut the power in a house.

Can you tell if a coconut is mouldy?

Carly Barratt

One way to test if your coconut has gone mouldy is to shake it. If you can't hear any liquid sloshing around inside, the coconut milk has probably gone rotten. However, fresh coconuts, which are light brown, may be so full of water that the liquid doesn't seem to move. You should also check that there is no whiteness on the coconut, indicating that the innards have gone mouldy and altered the outer appearance. Black spots on the top or bottom of the coconut can also indicate a similar problem. When buying a coconut, always check there are no cracks; these can indicate that air has gotten inside and the inner coconut will have been exposed, causing mould.

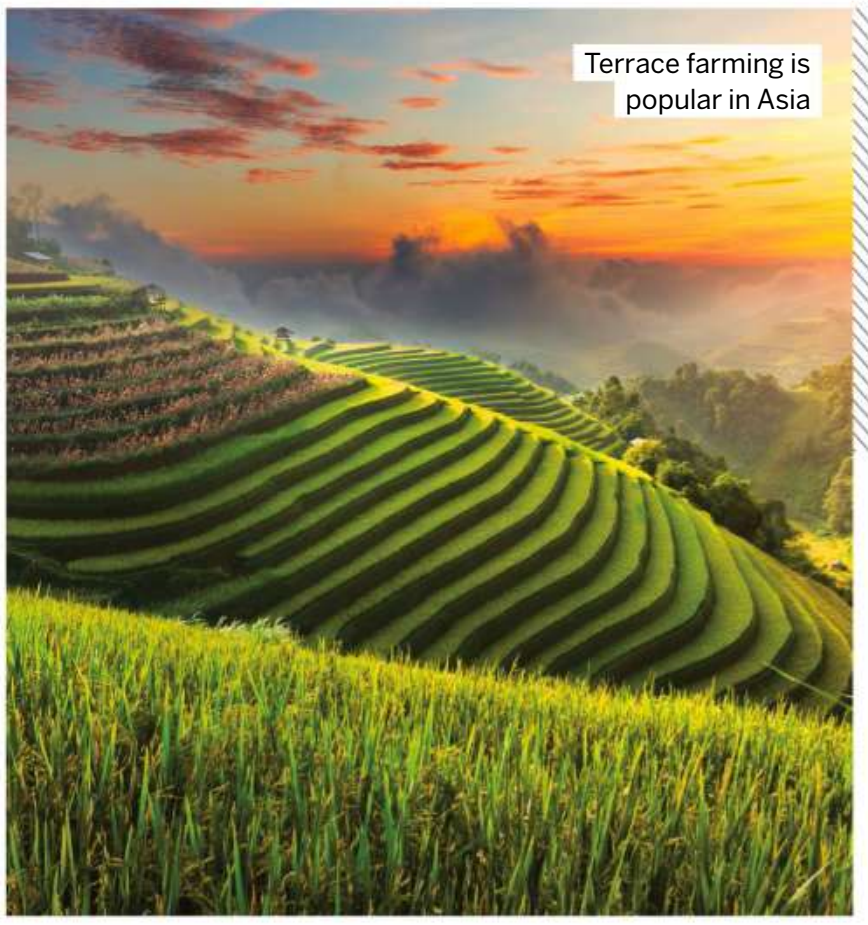
© Getty

BRAINDUMP

WHY DOES A SMELL SEEM TO FADE AFTER YOU GET USED TO IT?

Mark Stuart

Smell is the perception of odorants by our brains. Odorants are gaseous chemicals which stimulate sensory cells in our nose called olfactory sensory neurons. Just a few odorant molecules are enough to stimulate a sensory neuron, which starts to rapidly fire nerve impulses to the brain. The brain processes this and identifies the smell. If there is a constant odorant in the room our brain starts to perceive it as decreasing in intensity over time. This is due to a phenomenon called sensory adaptation, which isn't yet fully understood. During sensory adaptation our brain recognises the constant smell is not dangerous and stops identifying it so it's not overloaded with redundant information. Our olfactory sensory neurons also adapt to the repetitive odorant stimuli by reducing their rate of firing. Therefore we perceive the smell to be fading, allowing us to adapt to our environment and perceive new smells.



Terrace farming is popular in Asia

What is terrace farming?

Gerald Farnsworth

Terrace farming is used when the terrain is particularly hilly or steep. Terraces are made using low walls of earth up the side of the hills; these allow the farmers to make flat areas for planting their crops. The terraces act in several ways, but especially in allowing the soil to remain in place. Water flowing down the hill through natural gravity can be moved and channelled through the terrace set-up using a system of small openings and gates to allow different areas to be dry or wet at any one time.

WHAT ARE OWL PELLETS?

Robert Wise

As owls are carnivores, their prey can contain various body parts that are difficult to digest and hold little nutritional value, such as bones, fur, beaks and claws. Instead of passing through the intestines of the bird, these are coughed back up in the form of pellets. Owls and other birds, particularly birds of prey, produce pellets. You may have seen these when out walking – they tend to be about the size and shape of a cocktail sausage. They are normally blackish in colour, and you might notice a shiny or fluffy appearance. Pellets are a great way of finding out more about owl behaviour, and can even be used when surveying local prey populations – the remains found in the pellets tell researchers what prey are definitely in the area, and even give clues about where they nest.

WHAT'S IN FAKE TAN THAT MAKES OUR SKIN GO BROWN... OR ORANGE?

Alice Holloway

There are many different self-tan products on the market, but the most effective lotions and sprays contain dihydroxyacetone (DHA), a non-toxic, colourless sugar. The skin has two main layers: the epidermis on the outside and the dermis on the inside. DHA works by interacting with the proteins in the dead skin cells in the epidermis. The reaction results in a pigment called melanoidin, which makes your skin look brown.

Even though your skin looks brown, it will not protect you from the Sun's harmful ultraviolet rays, which penetrate deep into the dermis layer of the skin, damaging the cells and putting you at risk of skin cancer. Also, your fake tan will only last five to seven days – as your skin renews itself, the dead skin cells wear away, and so does your tan. Make sure you reapply every three days to keep your tan topped up, and don't forget the suncream.

Why do some metals melt?

Kate Sheffield

In solids, the atoms and molecules are held in a fixed arrangement by bonds, which are governed by electrostatic forces. Liquids occur when the atoms and molecules have more energy – they overcome these electrostatic forces to an extent and move about a bit. Different materials form bonds in different ways. If you're talking about elements and compounds, they will all be a liquid at some point given the right amount of energy, or a high enough temperature. However, lots of metals we know are alloys. Most alloys do not have a single melting point, but instead have a melting 'range' in which the alloy's a mixture of solid and liquid states.

Did you know?

Iron melts at 1,538 degrees Celsius

Most alloys have a melting range instead of a point

© Getty

What is the least inhabited place on Earth?

Gemma O'Connor

In terms of species richness, tropical areas tend to have more species, with most groups of plants and animals diminishing towards the poles. There are some exceptions to this rule, specifically penguins, which actually increase in richness towards the South Pole. The deep sea tends to be less rich than coastal habitats, though highly adapted species do exist in these regions – such as some anglerfish – where sunlight cannot penetrate, but at low abundance.

Anglerfish dwell deep beneath the ocean

Did you know?
Iron is the heaviest element a star can fuse

HOW DOES THE SUN BURN WITHOUT OXYGEN?

Oliver Rose

The Sun is an amazing source of energy, and people have long wondered how all that energy is produced. The word burning usually means combustion, and if the Sun was burning this way, it would indeed need oxygen. We're certain this isn't the case because the Sun wouldn't last for long. Nuclear reactions are the only source of energy able to keep the Sun shining for at least the age of the Solar System. When physicists say a star is burning hydrogen, they mean it's joining hydrogen atoms together to obtain helium and release energy. The exact name for this process is nuclear fusion. There's no need for oxygen in these nuclear reactions, but with respect to tradition, and as it's easy to simplify, astrophysicists use the word burn.

WHY DO BRUISES GO PURPLE?

Harry Anderson

Sometimes we hurt ourselves. When this happens, some of our blood vessels break, blood piles up under our skin and we see a bruise. These have the familiar 'black and blue' or purple appearance in the beginning, but gradually change to different colours. The purple is given by haemoglobin, a protein that carries the oxygen in our red blood cells. Our bodies react to this, with some white blood cells called phagocytes 'eating up' the materials in the bruise. As phagocytes degrade the haemoglobin, they turn it into other molecules. As you can imagine, different molecules show different colours, and the bruise will change colour with time to green, yellow and brown. When everything has been cleared up by your immune system the bruise disappears and you're ready to bump into something else.

WHAT IS THE GAIA HYPOTHESIS?

Ryan McDonald

102-year-old scientist James Lovelock

The Gaia hypothesis refers to the work of scientist James Lovelock, who looked at the feedback mechanisms in the cycles of nature between the inorganic Earth, the atmosphere and the living world. He pointed out that the cycles of things like oxygen, carbon, nitrogen and sulphur, through this 'biosphere', are both complex and interrelated. He argued they could be subject to rapid changes in equilibrium if unbalanced. This interacting system could then lead to feedback in the component systems so that within certain thresholds Earth would resist change in a stabilising behaviour in the global system. If pushed it would be subject to 'tipping points', leading to changes in global equilibrium.

While much of this is now accepted by science, it was initially very controversial. Lovelock's broad description is largely accepted today and informs our concerns about climate and biodiversity tipping points, which are a major threat to future global environmental security.

Why don't some birds fly?

Helen Ross

Unlike humans, who have always dreamt of flying, some birds will eagerly shed this evolutionary advantage if it no longer suits them. To remain airborne, it helps if you have hollow bones to keep weight down. However, if you're adapted to dive for fish, then having a denser structure helps you become less buoyant. Penguins use their flippers like wings to guide and propel their torpedo-like bodies through the water to catch fish and evade predators – they do fly in water, just not in air. Several families of birds have lost the power of flight, including many island forms. On small islands, being able to fly can be a disadvantage if you are likely to be blown out to sea by storms. Although regarded by some as flightless, the chicken and the jungle fowl – the chicken's Asian ancestor – have limited abilities, enabling them to flutter away from predators.

© Getty

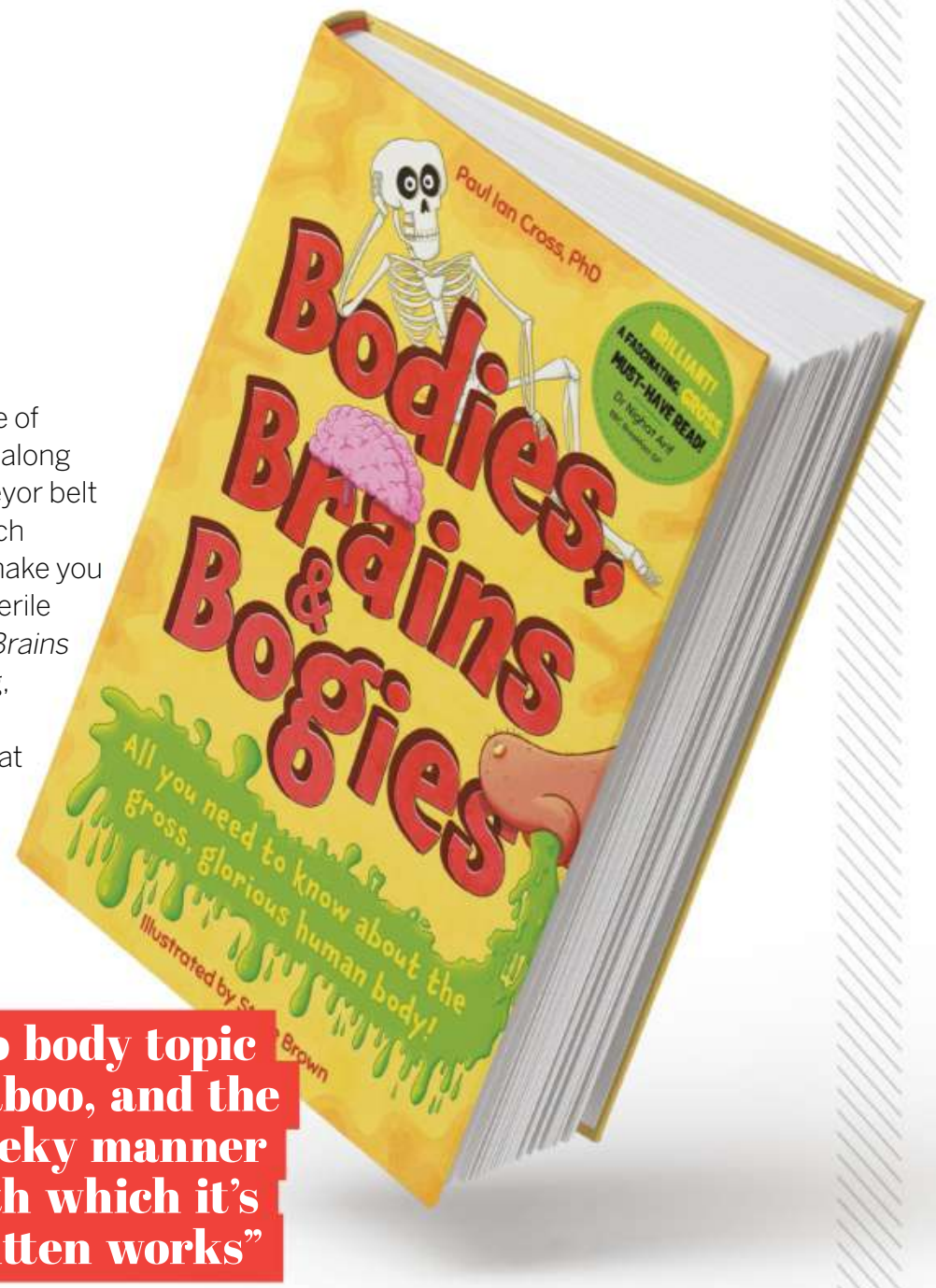
THE LIBRARY

The latest book releases for curious minds

BODIES, BRAINS & BOGIES

ALSO BURPS, FARTS, POOP AND SICK

AUTHOR **PAUL IAN CROSS**
ILLUSTRATOR **STEVE BROWN**
PUBLISHER **WELBECK PUBLISHING**
PRICE **£5.99 / $9.95**
RELEASE **21 JULY**

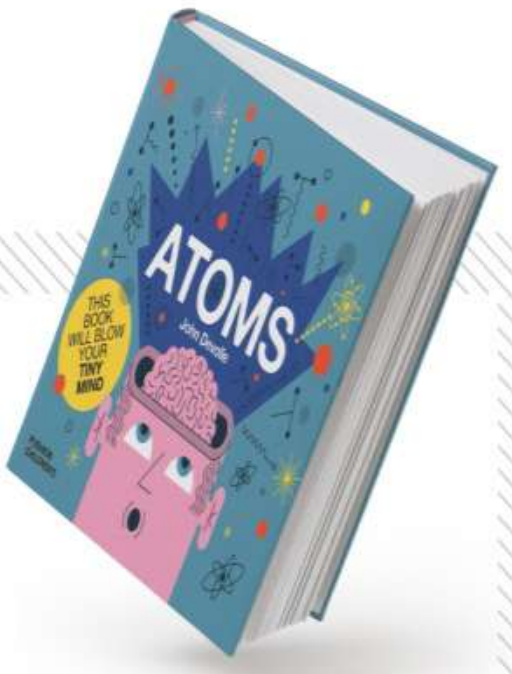

Paul Ian Cross, PhD
Bodies, Brains & Bogies
All you need to know about the gross, glorious human body!
Illustrated by S Brown
BRILLIANT! A FASCINATING, GROSS MUST-HAVE READ!

It's being sold on the promise of bogies, and bogies we get – along with farts, poop and a conveyor belt of bodily excreta. Pretty much everything you can think of that might make you gag and appeal to an eight-year-old's puerile sense of humour is included in *Bodies, Brains & Bogies*: pimples and pus, nose picking, urine and the 'poop factory' that is the human gut. And then there's the stuff that we largely don't expect but are equally grossed out about. Like the fact that there are over 1,000 species of bacteria living on your skin, making up a microbiome of billions of tiny individual organisms that are crawling around, eating and pooping on you. Think of that the next time you lick cheese and onion crisp flavour off your fingers.

> **"No body topic is taboo, and the cheeky manner with which it's written works"**

The author takes us on a journey from the top of the human body downwards, starting with the head and ending with... well, dreams and our minds, but before that human reproduction and all the icky stuff to do with your nether regions, including the changes we all experience during puberty. Between the facts and figures that are measurable by the 'Grossometer' – a four-point scale that goes from 'I can deal with this' to 'I'm going to be sick' – there are entire chapters devoted to equally fascinating but not quite as nauseating body topics like our lungs, how and why we breathe, singing and how other animals like fish and amphibians breathe. Moving a little further back up the torso, there's the heart, how it pumps and the composition of our blood. Steve Brown's supporting illustrations range from fairly academic and accessible cutaway drawings, like that of the inner ear complete with a wax-filled canal, to an outrageously grim picture of a teenager bursting a pimple and a very detailed illustration of a poop slipping into the toilet bowl.

Seems like no gross body topic is taboo here, and the cheeky, cheerful manner with which it's written works wonders. There's a precedent for this style, of course – with *Horrible Histories* springing to mind – but there's always room in the crowded educational book market for another book about bogies.



ATOMS

COMPLEX SCIENCE MADE SIMPLE

AUTHOR **JOHN DEVOLLE**
PUBLISHER **PUSHKIN CHILDREN'S BOOKS**
PRICE **£12.99 / $16.95**
RELEASE **OUT NOW**

The truly tiny size of an atom is difficult for many adults to comprehend, let alone children. But this book perfectly explains these particles in a visual way that could amaze minds as young as four years old. To grasp the extremely tiny nature of atoms, *Atoms* uses examples such as the printed full stops in the text – pointing out that there are more than a quintillion atoms making up just one of them.

Bold and quirky illustrations help explain that atoms are everywhere you look, with the images displaying the many forms they can take. Young readers may be amused to find out that the atoms that make up their bodies might have been part of another creature before them, perhaps providing a connection between them and the dinosaurs. The science about how atoms emerged and how they join together to form cells and organisms is broken into manageable sections, with cartoon depictions making it easy for young children to use their imagination. With basic yet incredible facts about the atoms that make up the world, by the end of the book children could be forgiven for thinking they'd read a piece of fiction.

MEET THE OCEANS

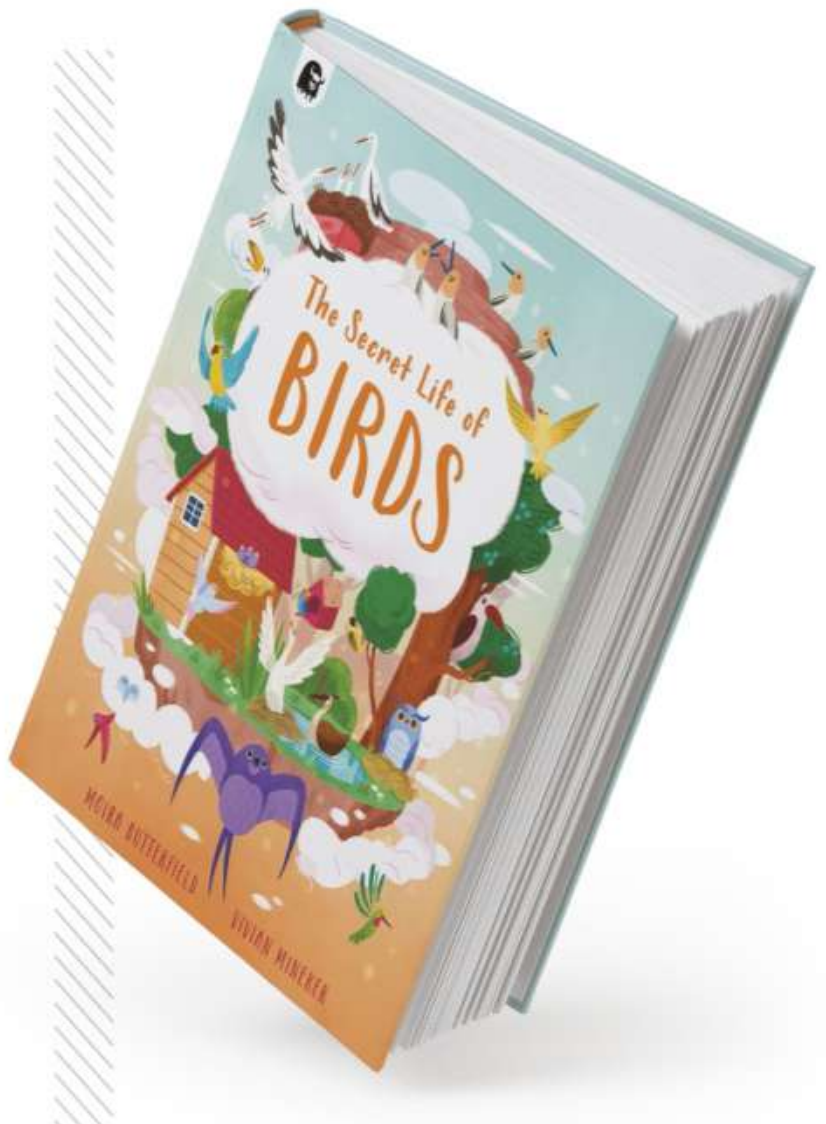
LET'S DIVE DOWN ON A JOURNEY TO THE DEEP

AUTHOR **CARYL HART**
ILLUSTRATOR **BETHAN WOOLLVIN**
PUBLISHER **BLOOMSBURY**
PRICE **£6.99 / $9.50**
RELEASE **OUT NOW**

This colourful, fun and informative children's book transports the reader into the depths of Earth's oceans. In an interesting twist that personifies each of the oceans and seas, children are provided with an engaging and relatable way to learn about the characteristics and conditions in these massive bodies of water. Each ocean introduces itself as an illustrated character and their dog pass through them in a submarine. From the plastic-polluted Pacific to the reef-embellished Coral Sea, each

destination comes with a fact-packed rhyme. These include details of the different species that live in each of the oceans, the hectic shipping lanes of the South China Sea and the icy conditions in the Arctic Sea.

As the character comes to the end of their action-filled global sea voyage, children are left with a final message to protect the oceans and seas. The beautifully vibrant and busy illustrations covering every ocean make this book perfectly designed to keep children entertained as they learn – using both imagery and words – about the diverse underwater world.



THE SECRET LIFE OF BIRDS

A GUIDE TO OUR WONDERFUL, DIVERSE FEATHERED FRIENDS

AUTHOR **MOIRA BUTTERFIELD**
ILLUSTRATOR **VIVIAN MINEKER**
PUBLISHER **FRANCES LINCOLN**
PRICE **£12.99 / $19.95**
RELEASE **OUT NOW**

The Secret Life of Birds isn't your typical children's book about birds. Along with the snippets of information related to how birds hunt, what they eat and where they live, woven throughout the book are fables, tales and fictional stories from around the world – for example, the tale of why the kookaburra laughs as told by the Aboriginal people of Australia and how the peacock got his colours from storytellers in India. There's also no scrimping on the factual information in this book; its pages are packed with insightful information about birds from around the world. *The Secret Life of Birds* will be sure to have your children begging for a pair of binoculars so they can find their nearest feathered friends. Thanks to the fictional elements, this book would also be a great addition to your bedtime library.

SCIENCE ILLUSTRATION

A HISTORY OF VISUAL KNOWLEDGE FROM THE 15TH CENTURY TO TODAY

AUTHOR **ANNA ESCARDÓ**
PUBLISHER **TASCHEN GMBH**
PRICE **£60 / $80**
RELEASE **OUT NOW**

If you're interested in the evolution of science and the history of human understanding, this is a great read. Century by century, *Science Illustration* takes its reader through images created to illustrate humankind's understanding of the world and beyond: from the first scientific illustrations of medicinal plants in the 1440s to the designs of modern-day feats of engineering like the Large Hadron Collider and three-dimensional depictions of microscopic structures such as coronavirus.

There are more than 300 graphics within the book that have been created by over 700 scientists across the breadth of scientific disciplines, including human anatomy, physics, chemistry and botany. Each of the graphics are accompanied by a bite-sized introduction into the

Science Illustration
A History of Visual Knowledge from the 15th Century to Today
SECTION OF THE EARTH
AT THE EQUATOR
TASCHEN

"There are more than 300 graphics within the book that have been created by over 700 scientists"

science they depict, as well as the significance of the illustrator's contribution to their field. *Science Illustration* is an extra-large-sized book, making it a great coffee table addition to flick through and discover something new about the wonders of our world.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

5				6	9		2	
	7		2	8	1	5		
			5			9	3	
6		7	9	2	4	1		
			6		5			2
	1	5	8	7	3		9	4
		2				3		
4	9		7		6		1	5
	5	3				4		8

MEDIUM

			8					9
9			6		7			2
8	3		9					1
	1					4	9	8
		5		9	2	1		6
				8		2		
						8	1	
			4	7		3	6	5
		6	5	1	8	9		

HARD

			8	9			2	7
8			6	3	5		9	
6	9	5	1					
		1	3	2	9			4
						6	7	
	7						4	
	4	9		7	6			

Word search

Find the following words

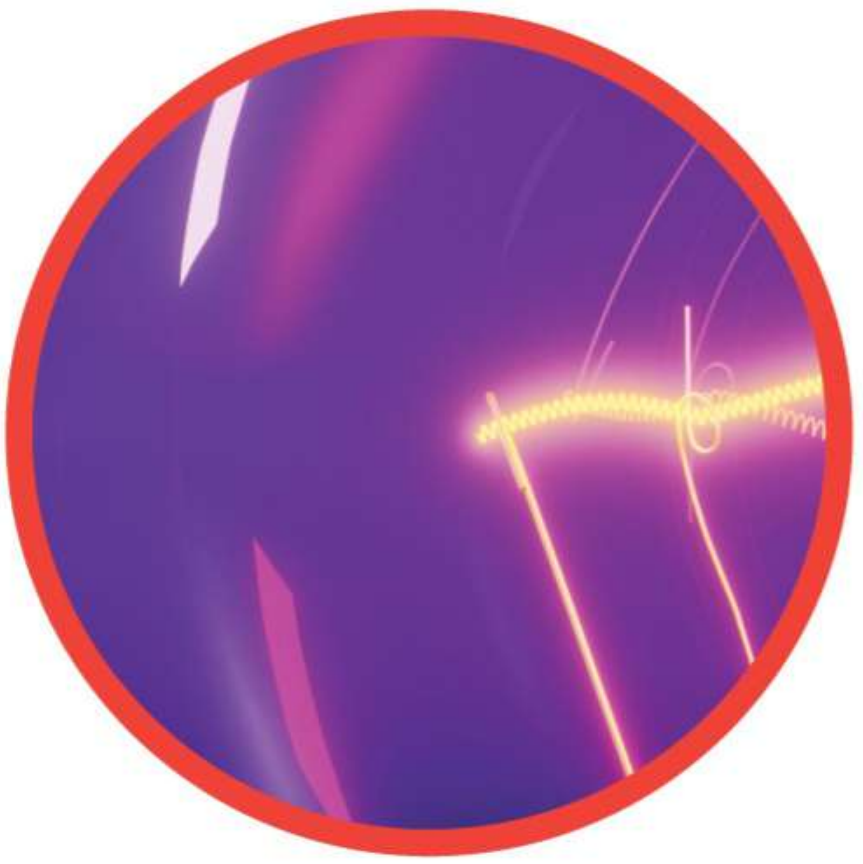
CLOCK
FJORD
BRAIN
ACCENT
LIGHTNING
DUST
SMART
TRACK
MITE
SKI
LASER
LIBERTY

C	R	Y	B	E	R	A	C	K	E	R	T	Y	O	T
E	L	O	B	L	I	B	E	R	T	Y	U	D	E	R
F	R	O	J	E	A	C	K	L	U	G	H	I	N	A
M	E	L	C	N	C	U	L	G	J	O	N	A	L	C
O	N	C	B	K	C	R	N	A	I	B	E	C	T	K
L	I	D	E	B	K	I	C	E	I	P	O	C	E	N
A	C	K	T	E	N	L	A	S	K	R	J	E	M	B
T	R	E	K	T	V	O	D	U	S	T	F	N	A	I
Y	P	O	H	T	R	I	C	H	C	L	U	T	R	W
B	A	G	L	R	X	F	J	O	R	D	V	S	P	T
R	I	A	N	E	L	I	V	E	R	Z	Y	O	I	M
L	I	G	H	S	O	E	X	F	G	K	C	Y	I	P
C	K	S	M	A	R	T	L	A	B	E	Y	T	O	B
E	R	E	C	L	H	E	X	O	P	A	E	T	R	A
R	Y	A	M	Z	Y	D	N	I	A	R	B	L	X	N

What is it?

Hint: Edison's bright idea

A



Spot the difference

See if you can find all six changes between the images below

Answers

Find the solutions to last issue's puzzle pages

Q1 CHINA
Q2 CAROTENOIDS
Q3 COLONY
Q4 13
Q5 EARS
Q6 IGNEOUS

What is it?

TYRE

Spot the difference

QUICKFIRE QUESTIONS

Q1 How many breaths do we take in an average lifetime?

- 10,000
- 90 million
- 300 million
- 850 million

Q2 What is a group of ladybirds called?

- Crowd
- Gaggle
- Loveliness
- Group

Q3 When did the world's oldest intact shipwreck sink?

- 1200 BCE
- 400 BCE
- 400 CE
- 1200 CE

Q4 Which part of a cell holds the DNA?

- Mitochondria
- Nucleus
- Cytoplasm
- Lock

Q5 What is the width of the Milky Way Galaxy?

- 105,700 metres
- 105,700 miles
- 105.7 billion miles
- 105,700 light years

Q6 What percentage of the Sahara is sand?

- 20
- 40
- 80
- 100

© Alamy / Getty

HOW TO...

Practical projects to try at home

MAKE A BUBBLE SNAKE

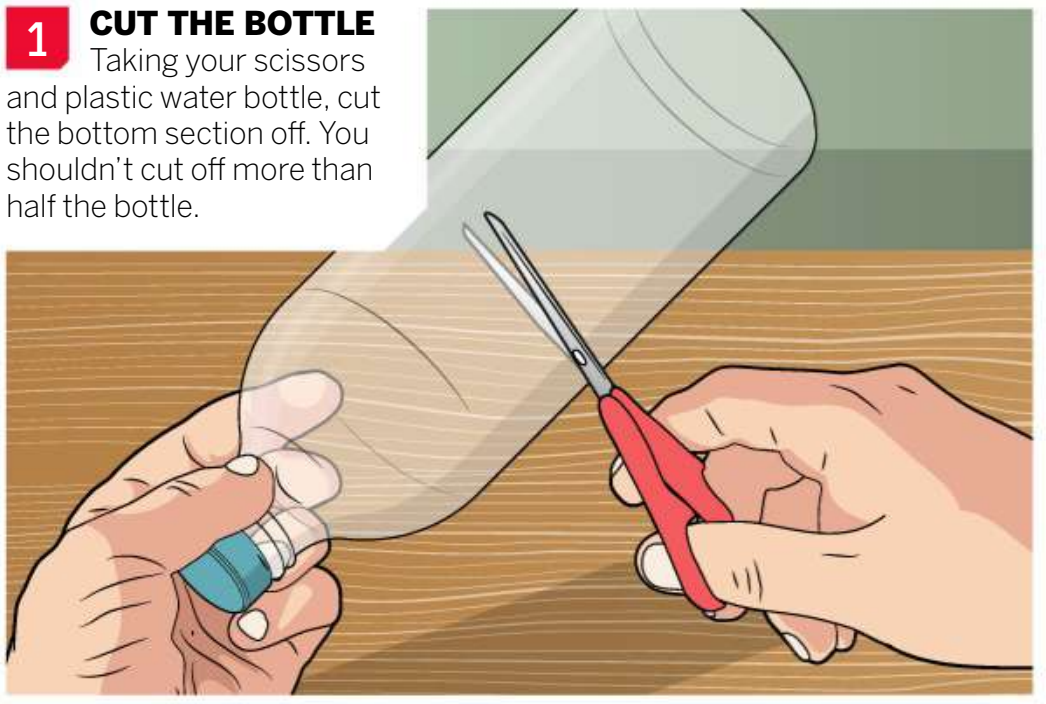
Create your own bubble-blowing machine in this simple experiment

KIT LIST

- Plastic water bottle
- Shallow container
- A sock
- Strong tape
- Dish soap
- Scissors

1 CUT THE BOTTLE

Taking your scissors and plastic water bottle, cut the bottom section off. You shouldn't cut off more than half the bottle.



2 COVER WITH THE SOCK

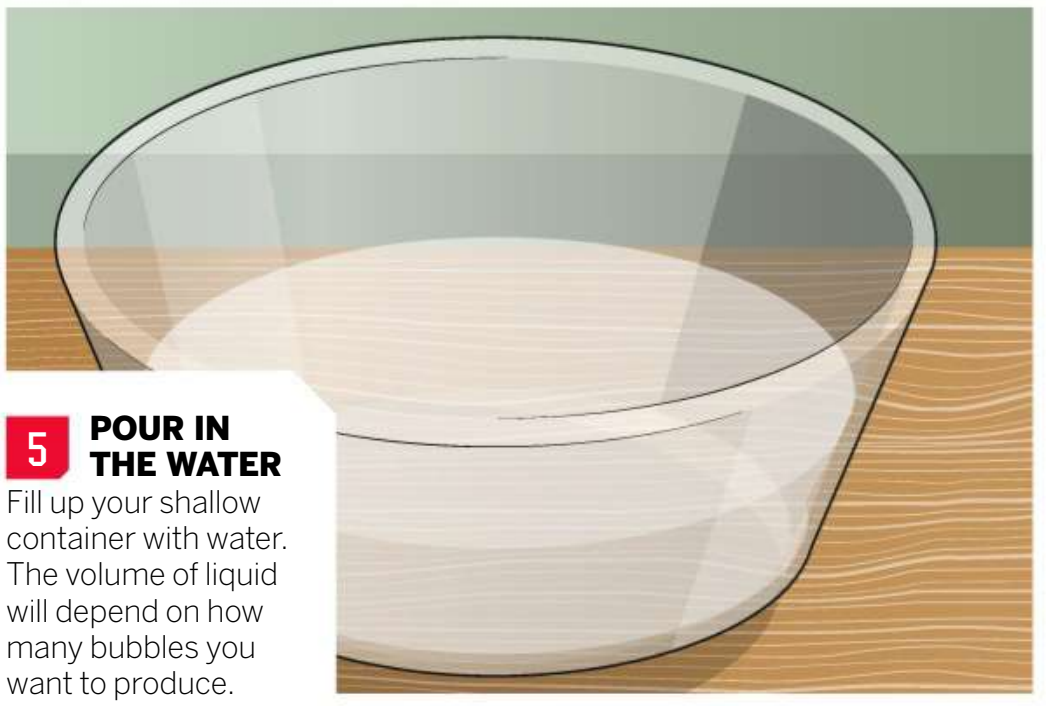
Insert the cut-open end of the top half of the bottle into your sock. Use any socks that have lost their pair, or an old sock.

3 NEATLY FOLD

Push the sock right over the bottle so that there's no sock hanging down. You can fold over any excess sock that extends past the bottle opening.

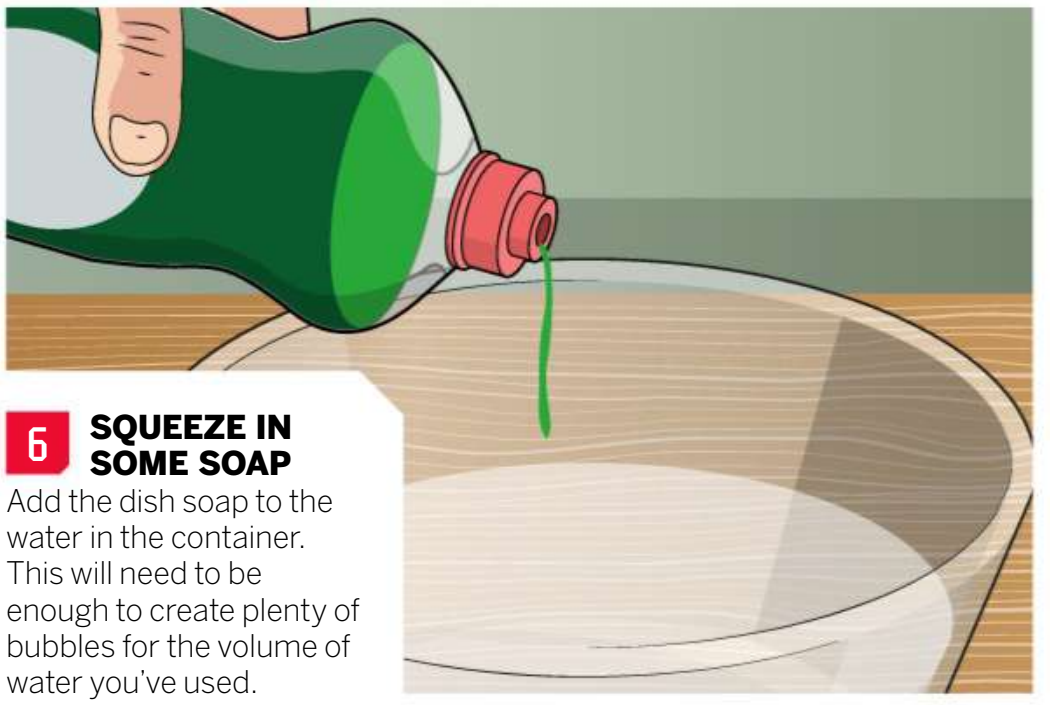
4 SECURE WITH TAPE

Using relatively strong tape, such as duct tape, secure your sock in place. This is mainly needed for the loose sock near the neck of the bottle.



5 POUR IN THE WATER

Fill up your shallow container with water. The volume of liquid will depend on how many bubbles you want to produce.



6 SQUEEZE IN SOME SOAP

Add the dish soap to the water in the container. This will need to be enough to create plenty of bubbles for the volume of water you've used.

NEXT ISSUE
HOW TO LAUNCH A TEA-BAG ROCKET

DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you

7 MIX THOROUGHLY
Using your hand or a spoon, forcefully mix the dish soap into the water. Some bubbles should begin to form at the water's surface.

8 DIP THE SOCK
Lower the sock end of your bubble-blowing machine into the water so that it's submerged by a few centimetres.

9 BLOW THE BOTTLE
Using the opening of the bottle as a mouthpiece, gently blow into the bottle and watch as a bubbly snake is created. It's important that you don't suck any air in– you don't want to eat the soap!

SUMMARY

This serpentine bubble shape is a result of many tiny bubbles forming and sticking together. In the sock, there are many small holes between threads of cotton. After the sock is dipped into the dish soap and water, flat films of soap cover these holes. If you blow air through the bottle gently enough so that you don't break the bubbles before they form, the bubbly film expands as the air shapes it.

If you want to add more effects to your bubble snake, why not try adding some food colouring to your soap-and-water mixture? This can be messy, so take care not to touch the liquid with your hands after adding the colouring. If you don't mix the food colouring too much, each of the colours will be visible in the final result, so you can create different varieties of rainbow bubble snakes.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX
Speak your mind

GOLFTECH PRECISION

Dear **HIW**,
I've recently subscribed to your excellent magazine. I've been watching a lot of golf lately and I'm wondering if someone could explain how things like TrackMan follow the flight of a golf ball after it's been hit. It seems incredible that it can highlight the curve, height and distance for hitting something which is quite small. You may have featured this tech in a previous issue, but with the US Open and British Open still to be played this year, it would be nice to know how this magic happens.
Allan Bannerman

Thanks for getting in touch Allan, and welcome to How It Works. TrackMan is one of the most widely used monitors used to collect data during large golf tournaments. It uses two different radars to track the movement of both the golf clubs' heads and the golf balls as they travel through the air. The direction and angle of a club's swing is determined using 4,000 data points per 0.1 seconds. Doppler radar measures the speed of the club and the ball as it is launched into the air. As microwave signals are sent out from the TrackMan device, which is placed around the player, the signals bounce off moving objects. This causes a change in signal frequency that is directly proportional to the speed of the moving object.

At 90 metres, TrackMan can pinpoint the landing spot of a golf ball with an accuracy within 30 centimetres. Today's TrackMans have ultra-high-frequency radars, allowing for the balls' paths to be closely and accurately tracked. This radar is backed up by a HD video camera so that the movements can be synchronised.

TrackMan devices can be seen placed behind this golf player

LETTER of the MONTH

WIN!
AN AMAZING PRIZE FOR LETTER OF THE MONTH
BODIES, BRAINS & BOGIES
Find out everything about poop, pus and bogies while learning a whole lot about how our bodies work hard in hundreds of fascinating ways to keep us alive.

EARLY GROOMING

Dear **HIW**,
When were combs and scissors invented for people to keep their hair tidy? And how did primitive men keep their moustaches in order before they had them? It would surely be a nightmare eating with an untrimmed moustache.
Stephen

Before scissors were invented, people cut their hair using knives instead. The first scissors emerged around 1500 BC in Egypt, but they weren't invented for this purpose. Instead they served as and looked more like small shears made from a single piece of metal. It was only later, when the Romans designed tools more like today's scissors, that they were used for cutting hair. Earlier humans, such as those alive during the Stone Age, were experts at crafting sharp tools, such as flints, from stone. There's also evidence of early humans growing their hair long and braiding it.

The Romans adapted scissors to give them their cross-cut action

THE CHEESE FACTORY

Dear **HIW**,
I recently had a Babybel and it made me wonder how they are packaged. What is the waxy layer made of and how is it wrapped around the cheese without it sticking to it?
Camille Wright

The cheese is dipped in wax. This includes a clear and a coloured layer. Wax used for cheese preservation is specifically made so that it holds together well. Unlike 100 per cent paraffin wax, when the wax used to wrap cheese hardens, it remains relatively soft and bendy. When it's pulled apart, it peels easily and in large pieces. Wax used to wrap Babybels has been tested to make sure that even if bits of it are ingested, it isn't dangerous.

The wax of a Babybel can be torn in the middle

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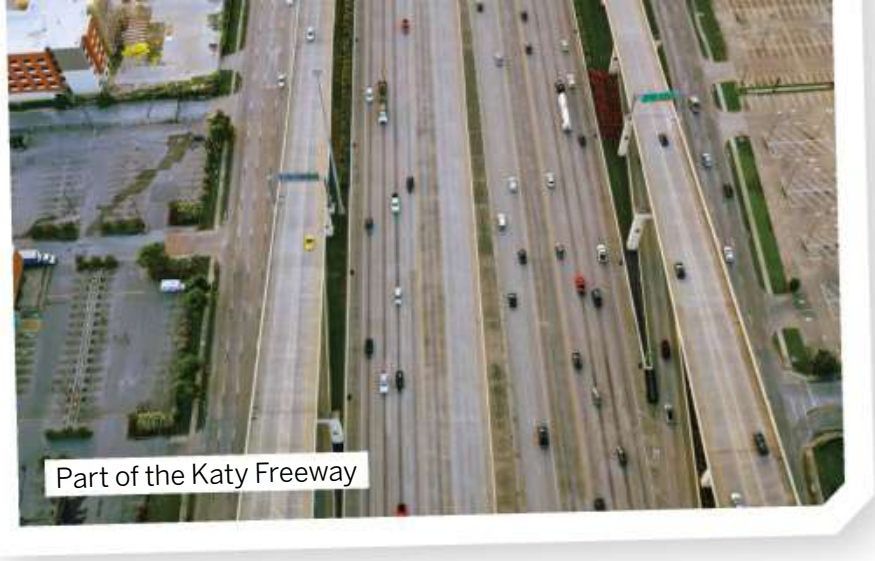

Part of the Katy Freeway

ROADS OF THE WORLD

Dear **HIW**,
Of all the countries in the world, which has the most roads? And how much space is covered in roads there?
Graham Rainsley

The United States has more road space than any other country in the world. Its roadways make up more than 3.7 million miles, with China having the second most at close to 3.1 million miles. Most of these roads are connected. Interestingly, the world's widest freeway also tracks across the US. The Katy Freeway, also known as Interstate 10, has 26 lanes.

To make coffee using instant coffee, you just need to add boiling water

COFFEE QUESTION

Dear **HIW**,
How are coffee beans turned into instant coffee?
Stefan Lewis

Thanks for your question Stefan. Most of the coffee you have come across is likely to be instant coffee, as around half of all harvested coffee is made into instant coffee. First, coffee beans are cleaned and roasted at 230 degrees Celsius. When they are cool again, the beans are ground, with any lost aromas pumped with nitrogen into a tank. Next, the coffee is brewed and evaporated so that thick coffee syrup remains. When this syrup is frozen and broken into granules, all there is left to do is store them in low pressure for several hours and spray the lost aromas onto them to produce instant coffee.

WE ASKED YOU

This month on social media, we asked you: Which of the world's constructed landmarks is the most impressive?

@AMBERDARCY
Sagrada Familia

@SAMMY.GLANFIELD
The Great Pyramids in Egypt because of how limited the technology was then

@DUTRZ
My favourite is the Great Sphinx of Giza because it has lasted for more than 4,500 years

@_ROSS_1468
Burj Khalifa

@CAROLJSHELDON
Empire State Building

@AESTHETICALLY_AJ
The Moai (Easter Island heads). Because each one took about a year to complete!

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HOW IT WORKS

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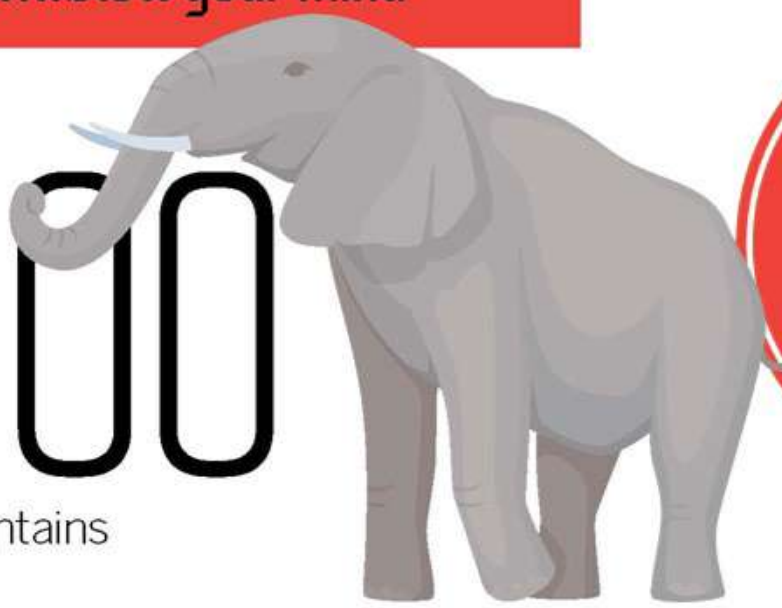
FAST FACTS

Amazing trivia that will blow your mind

40,000



An elephant's trunk contains thousands of muscles

1,000 YEARS

A plastic bag is used for an average of 12 minutes but takes a millennium to biodegrade

0.3 MILLIMETRES

The world's smallest computer is a fraction the size of a single grain of rice

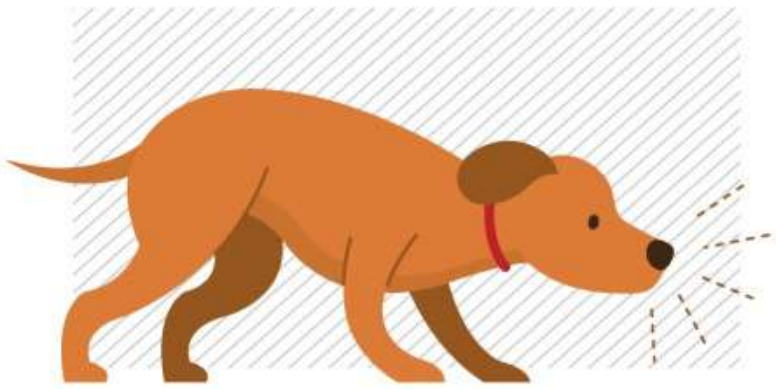
1,460,000 MILES

In its lifetime, an Arctic tern will fly the equivalent of three return trips to the Moon

1858

Until this year, all UK passports were written in French

Mosquitoes prefer to bite people who have recently drunk alcohol



007

The dialing code from the UK to Russia has a suspicious ring to it

PENGUINS ARE UNABLE TO TASTE FISH

DOGS CAN SMELL THE DIFFERENCE BETWEEN IDENTICAL TWINS

27,000

Slugs have thousands of tiny teeth

373 MILES PER SECOND

The velocity at which the Milky Way moves through the universe

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The countdown is on for our brilliant Summer of Reading live event! It's happening on Saturday 16 July at the British Library in London. Featuring your favourite authors live on stage, this event aims to really spark your imagination.

BRAND NEW!

The British Library, London

Saturday 16 July 2022
9.30am – 5.00pm

Here's a sneak peek at the lineup. Be sure to keep an eye on the website for the full list of sessions and fantastic authors to see on the day!

ELLE MCNICOLL, PETER BUNZL, CERRIE BURNELL AND JOSEPH COELHO, THE GREAT FAIRYTALE DEBATE

2.45pm - 3.30pm

Join four authors of spellbinding magical stories – Peter Bunzl, *Magicborn*, Cerrie Burnell, *Wilder than Midnight*, Joseph Coelho, *Fairytales Gone Bad* and Elle McNicoll, *Like a Charm* – for this enchanting event. Together, they'll be debating which is the greatest fairytale of them all...

M.G. LEONARD AND SAM SEDGMAN, *ADVENTURES ON TRAINS*

11.30am - 12.30pm

All aboard the fifth book in the award-winning series from M.G. Leonard and Sam Sedgman. Join the best-selling authors on stage as they bring to life *Adventures on Trains: Sabotage on the Solar Express*, a thrilling and hugely entertaining adventure story. Hear how the duo started their love for writing children's books together, as well as the inspiration behind the book.

SHARNA JACKSON, *THE GOOD TURN*

10.30am - 11.15am

Join Sharna Jackson as she discusses her intriguing new mystery adventure, including the historical inspiration behind the book, how you can be inspired to care for your community – plus learn how to write and solve your very own mystery.

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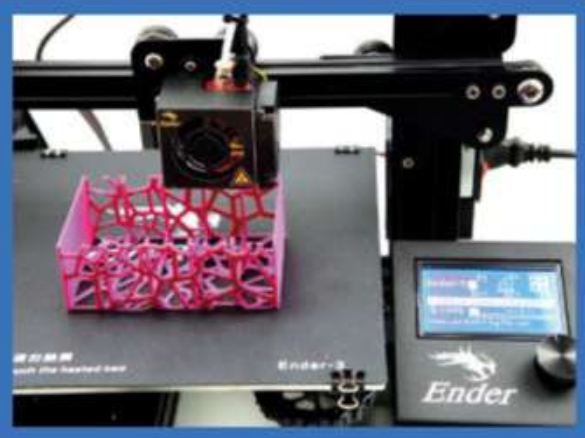

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